NATIONAL

ACADEMY OF SCIENCES

OF THE UNITED STATES

OF AMERICA

---

# BIOGRAPHICAL MEMOIRS

VOL. XXII

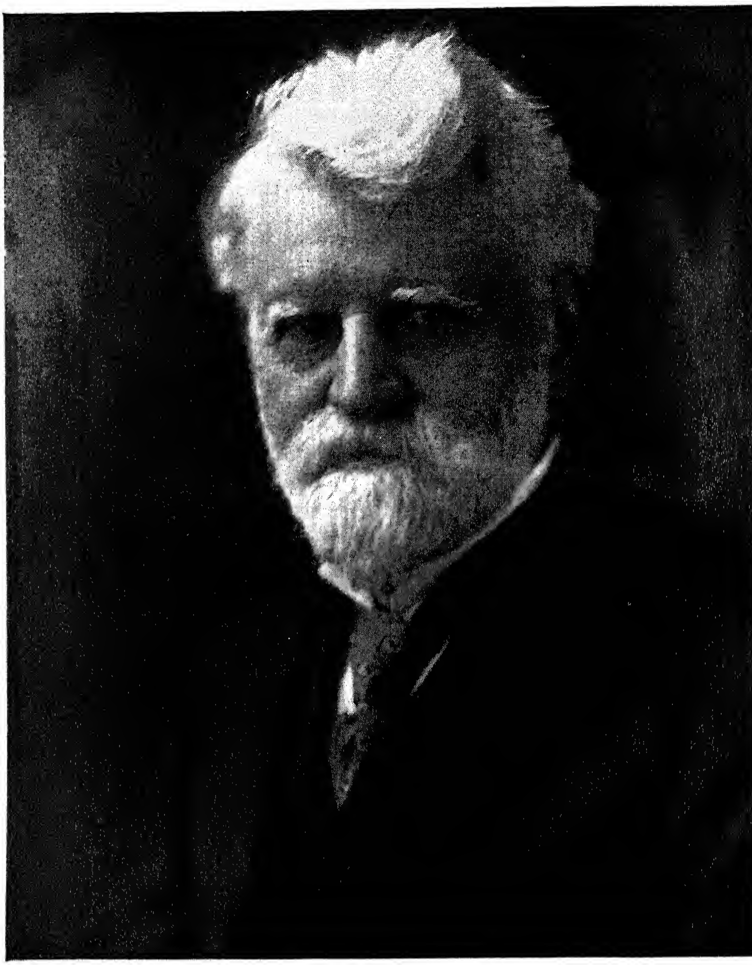
---

CITY OF WASHINGTON

PUBLISHED BY THE NATIONAL ACADEMY OF SCIENCES

1943

# CONTENTS



Ambrose Swasey

NATIONAL ACADEMY OF SCIENCES

OF THE UNITED STATES OF AMERICA

BIOGRAPHICAL MEMOIRS

VOLUME XXII—FIRST MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# AMBROSE SWASEY

1846–1937

BY

DAYTON C. MILLER

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1940

# AMBROSE SWASEY

## 1846–1937

BY DAYTON C. MILLER

Ambrose Swasey, engineer, scientist, philanthropist, was born in Exeter, New Hampshire, on December 19, 1846; he died at the old homestead on the farm where he was born on June 15, 1937, aged 90 years and 6 months.

A group of pioneers, four hundred in number, including four non-conformist clergymen, came from old England to New England in the spring of 1629. John Swasey, founder of the Swasey family in America, and his two sons, Joseph and John, Jr., presumably were members of this group and they settled in Salem, Massachusetts.[1] The Governor of Salem, John Endecott, in this time of religious intolerance, showed great bigotry and harshness and expelled all Baptists, Episcopalians, and Quakers. John Swasey, being of the latter faith, was obliged to leave, about 1650, going to Satauket and later to Southold on Long Island. Joseph Swasey (second generation) the eldest son of John Swasey, remained in Salem and followed the humble occupation of fisherman. Joseph was one of the charter members of the first church organized in Salem, in 1629, this being the first Congregational Church in America. This Joseph Swasey had a son named Joseph (third generation) born in 1653 in Salem. The further line of descent is: Joseph, born in 1685, in Salem; Ebenezer, born in 1727, in Old Newbury, Massachusetts; Ebenezer, born in 1758, in Old Newbury; Nathaniel, born in 1800, in Exeter, New Hampshire.

Ambrose Swasey, the son of Nathaniel and Abigail Chesley Peavey Swasey, born in Exeter, New Hampshire, December 19, 1846, was the ninth in the family of ten children, seven sons and three daughters. Seven of the children lived to maturity, and reached ages of 30, 63, 69, 75, 76, 84, and 90 years.

The father, Nathaniel Swasey, who lived 90 years, "loved the work of farming"; he was active in the affairs of his native

[1] Benjamin Franklin Swasey, *Genealogy of the Swasey Family*, Cleveland, Ohio, Privately printed, 1910, 525 pages, with portraits and illustrations.

town, Exeter, and was elected to the Board of Selectmen in 1847-1848; in 1852 he introduced the first practical mowing machine in his county; his farm was developed and enlarged until it contained 250 acres. In addition to the training in the public schools, he received private tuition from a member of the faculty of Phillips Exeter Academy. His favorite studies were arithmetic, astronomy, ancient history, literature and poetry.

The mother, Abigail Peavey Swasey, died at the age of 77 years. "She was of a cheerful disposition and possessed refined manners; she loved above all else her home and children; she was an exemplary Christian and strove to inculcate in the minds of her children the importance of a religious life." Together with her husband, she joined the Baptist Church in 1840.

Ambrose Swasey once said, "All my brothers and sisters went to academies or colleges, but my only schooling came from the little country grammar school" at Exeter. However, his remarkable career is incontestable evidence that his real education continued without abatement throughout his life. Seven universities recognized his scholarly attainments by conferring honorary degrees, one "Doctor of Engineering," three "Doctor of Science" and three "Doctor of Laws".

There were no mechanical toys when Ambrose was very young but he soon learned to make his own. Mother's old spinning wheel and his jack knife helped in making a flax wheel. The old attic was his workshop and there he set up an improvised lathe. Then he made a working model of a mowing machine which is still in existence. Boys on old New England farms all had duties and Ambrose was in charge of the sheep and lambs which he loved and gently cared for. He was interested in music and played the flute. When he was eighteen years old, in 1865, his bent for machines and mechanical instruments prevailed, and he decided to enter upon a three-year apprenticeship in the newly established Exeter Machine Works.

Another young man of the same age as Ambrose Swasey, Worcester Reed Warner, born in Cummington, Massachusetts, in 1846, had no liking for farming as a life work and in 1865 he secured his first employment in the draughting room of the American Safety Steam and Engine Company of Boston. A few

months later the company transferred its work to Exeter, New Hampshire, and Warner went with them; he then entered upon an apprenticeship in the same shop where Swasey was working. The two enthusiasts soon became warm friends. As Ambrose started ahead of Worcester in the apprentice work, he finished first, and then to widen his experience he went to Paterson, New Jersey, to enter the employ of the Grant Locomotive Works. He soon found the work unsuited to his inclinations and perhaps, too, a bit of homesickness hastened his return to Exeter. Once again the two young friends spent the winter working in the shop, living and studying together, and planning for the future.

After Worcester Warner had completed his apprenticeship, the two young men started out to make their fortunes. In the spring of 1869 they wrote letters to four large manufacturing concerns, seeking positions as machinists, and received offers of positions from all four companies. As was to be expected, they chose to accept offers from the same concern, the Pratt and Whitney Company of Hartford, Connecticut, manufacturers of precision tools and machinery. After their first day's work, Warner remarked to Swasey, "Well, Ambrose, we have a very difficult job; there must be five hundred men ahead of us." However, they soon attracted attention by their special abilities in solving mechanical problems, and were advanced in rank so that the number of men ahead of them decreased.

In 1875 Ambrose Swasey received his first patent for the invention of an improved protractor for measuring angles with extreme accuracy. Thus is recorded one of the prominent characteristics of his entire life, the attainment of truth and precision. In the same year, a second patent was issued to him for an improved water meter.

In 1878, at the age of 32 years, Mr. Swasey was made superintendent of the gear cutting department of the Pratt and Whitney Company. He spent long evenings in his room studying books on machinery; his mechanical genius rapidly developed improvements in shop methods and eventually, in 1879, lead to the design and construction of the Epicycloidal Milling Machine for producing true theoretical curves from which cutters for gear teeth are made. He invented also a new gear-cutting

machine for generating and at the same time cutting the teeth of spur gears, the process being a solution of the difficult problem in the interchangeable system of gearing.

Ambrose Swasey's breadth of knowledge, both practical and theoretical, was recognized in high places for, in 1879, he was visited at his work in the shop by a college official who offered him the position of Instructor in Mechanic Arts at Cornell University as the successor of Professor John E. Sweet. It was one of the greatest surprises of his life—that he, a youngster without college training, should be urged to enter upon such a career. He modestly underrated his own ability and the breadth and value of the training to be had in the old machine shops where men found joy in good workmanship, and in the training he had received on his father's fine old New England farm. He declined the invitation from Cornell University.

After eleven years with the Pratt and Whitney Company, in the spring of 1880, the two friends, Worcester Reed Warner and Ambrose Swasey, decided to go into the machine-tool business for themselves, in Chicago, under the firm name of WARNER & SWASEY, their initial investment being their combined savings up to that time, five thousand dollars. Four young men of Connecticut, George C. Bardons, William S. Lane, George D. Phelps, and Frank H. Woods, went with them and formed the nucleus of the new organization. After an experience of one year it appeared that this location was too far removed from the industrial east where their products were mostly used and from which they obtained supplies and skilled labor. They chose Cleveland, Ohio, as the location for their business, and early in 1881 Mr. Warner went to Cleveland to supervise the construction of their new shop on the site occupied by a portion of their present plant. On July 8, 1881, Ambrose Swasey came to Cleveland to join his partner; he was destined to become one of the city's most useful, most loved and most honored citizens.

The first order received by Warner and Swasey was for twelve hand lathes, from the Crane Company of Chicago. Machines for milling the cams of sewing machines were designed

and constructed; vertical milling machines for die sinking and similar purposes were made in large quantities. An important development was a horizontal boring machine. Later much attention was given to highly specialized brass-working machine tools. The turret lathe was destined from the beginning to be the principal product of the company. With the rapid growth of the modern method of interchangeable parts, a standard line of turret lathes was developed. The introduction of turret lathes in European countries, in unprecedented quantities, brought about further specialization in the product and a marked increase in production.

The business grew; but not as fast as might have been. These men were not primarily interested in mass production and mere money making. Mr. Swasey once said: "If we double our production, we must double the size of our shops. Then Warner and I would no longer be cheerful on top of our job, but would be bowed down beneath its burdens. As things now are, we have leisure to satisfy our individual fondnesses for fine mechanism, leisure to travel and to look about us, to pass some time with our friends and have time really to enjoy the good things of life."

The two men were so absorbed in designing and making fine machines, and their mutual trust was so great that they did not take the trouble to draw up a written agreement of partnership until the year 1900. In this year they organized and incorporated The Warner and Swasey Company. The company has branch offices in twelve cities in the United States and has three agencies in Canada and thirteen agencies in foreign countries, including Australia, Japan and India.

In his youth Worcester Warner found especial delight in the study of astronomy; his mother was a lover of books and a woman of exceptional intelligence, and gave him encouragement. He made a simple telescope with such means as were available. During his apprenticeship he continued his investigations and experiments, and later, in Hartford, in his leisure hours, he constructed a mounting for a portable telescope. This proved to be such a success that he built a still larger and more powerful

instrument. He drew his inspiration from such books as Mitchell's "Planetary and Stellar Worlds" and Burritt's "Geography of the Heavens."

Worcester Warner's enthusiasm for astronomy was absorbed and radiated by his companion and partner, Ambrose Swasey. During the few months when they were located in Chicago, they received orders for several small telescopes, such as had previously been made for their own use. It seems a most fortunate circumstance for the world of science that these two men, Ambrose Swasey and Worcester R. Warner, should have associated as partners. Although the making of astronomical instruments was not included in their original plans, yet Mr. Warner's interest in astronomy, combined with Mr. Swasey's exceptional ability as a mechanical engineer, very naturally led them to apply their facilities to the construction of astronomical instruments.

Early in 1881, in their Chicago factory, Warner and Swasey completed their first real astronomical telescope, an equatorial mounting of new design, for a nine and one-half inch object glass. This telescope, upon the recommendation of Mr. S. W. Burnham of Chicago, famous for his observations of double stars, was acquired by Beloit College, Beloit, Wisconsin. This first telescope gives evidence of Mr. Swasey's inherent characteristics in designing, efficiency, precision, and "architectural" beauty.

In 1882, a revolving dome, forty-five feet in diameter, was constructed to cover the 26-inch refracting telescope of the Leander McCormick Observatory of the University of Virginia. This dome represented marked improvements in design, as regards the operation of the shutter and the rotation of the structure. It moves with such ease that it may be revolved by the pull of one hand on the rope.

The design and construction of the Lick telescope was epoch making both in the science of astronomy and in the careers of Mr. Swasey and Mr. Warner. An authoritative account of the significance of this event was given by Dr. W. W. Campbell, President of the University of California and Director of the Lick Observatory, on April 23, 1924, when the American Society of Mechanical Engineers conferred the John Fritz Medal upon

Mr. Ambrose Swasey.[2] Extracts from this address are here given:

"Dr. Ambrose Swasey's introduction to astronomy and astronomers occurred under unique and interesting conditions. In 1874, just 50 years ago, James Lick, a Pennsylvanian by birth and a Californian by adoption, gave to a Board of Trustees of the University of California the sum of $700,000, 'to provide for the construction of a telescope larger and more powerful than any in existence, and a suitable observatory connected therewith.' The Trustees commissioned Prof. Simon Newcomb to visit all established makers of optical glass, lenses, and telescope mountings to secure data and advice which would guide them in deciding upon the size and kind of telescope to be constructed. The final decision was in favor of a 36-inch refractor. The making of the glass in the rough was entrusted to Feil & Son of Paris. The figuring and polishing of the glasses was undertaken by Alvan Clark & Sons, of Cambridgeport (now Cambridge), Massachusetts.

"There remained the extremely important question of the mechanical mounting of the telescope. The Trustees invited tenders of designs and bids, and several firms in Europe and America complied. The list included the leading builders of telescopes and one recently established firm, Warner & Swasey, of Cleveland, Ohio, then unknown to astronomers. The several plans were given consideration by experienced astronomers and engineers, as befitted the high responsibility, and by unanimous decision of the Trustees the award went to Warner & Swasey. It is worth noting that theirs was the highest of all the bids, but their design was so clearly the best that the firm's inexperience in constructing telescope mountings was not permitted to influence the decision.

"In due time, in 1888, the James Lick telescope was erected on Mount Hamilton in California, fifty miles south of San Francisco, and put into commission. It was immediately satisfactory and successful in all of its parts and as a whole. In power and applicability it surpassed the expectation of astronomers everywhere. It immediately became, and for more than two decades remained, the leading astronomical instrument of its time. The bearings which guide its movements are so perfect that, although it weighs many tons, it can be swung easily from one position to another by hand. For 33 years I have made personal use of it

[2] *Mechanical Engineering*, **46**, 368 (June, 1924). Edward S. Holden, *The Sidereal Messenger*, **7**, 49-65 (1888). Simon Newcomb, *Harper's Monthly*, **70**, 399-406 (1885).

and my admiration for its design and workmanship has remained unabated. The instrument has been used through every good night in the last 36 years, save possibly half a dozen nights when the dome or some detail of the telescope mechanism was undergoing repair, and it works as well today (1924) as it did in 1888."

The plans for the Lick telescope called for an instrument to be used not only for visual observations but also for photographic and spectroscopic researches, specifications which were involved for the first time in the design of a large telescope. Mr. Swasey's design was novel and original and included polar and declination axes of steel with ball bearings and improved counterbalancing, besides many conveniences for the operation of the giant telescope.

Mr. Swasey went to Mount Hamilton in November, 1887, to supervise the erection of the telescope on the completed masonry foundation. The steel tube of the telescope is about 57 feet long. The 36-inch objective was mounted on the end of the tube by its maker, Alvan Clark, Junior, on December 31, 1887, and he was much perturbed when it was discovered that the focal length of the objective was six inches less than was specified in the order. Mr. Swasey soon relieved Mr. Clark's anxiety, and the next morning he proceeded to cut six inches off the lower end of the tube with a hack saw and to refit the breech block. On January 3, 1888, the telescope was first used to observe the star Aldebaran and the great Nebula in Orion, by Captain Richard H. Floyd, chairman of the Lick Trust, Mr. Swasey, Mr. Alvan Clark, Jr., and astronomer James E. Keeler. The performance of the telescope was highly satisfactory.

The Lick telescope proved to be so efficient that the United States Government, in 1893, commissioned Warner & Swasey to provide an entire new mounting for the 26-inch objective lens belonging to the United States Naval Observatory in Washington, and to equip the observatory with an elevating floor and a new dome.

The next great telescope of Mr. Swasey's design is the 40-inch refracting telescope of the Yerkes Observatory of the University of Chicago, located at Williams Bay, on Lake Geneva, Wiscon-

sin, together with the revolving dome ninety feet in diameter and the elevating floor seventy-five feet in diameter with a rise and fall of twenty-five feet. The telescope mounting was exhibited at the World's Columbian Exposition in Chicago in 1893, and was mounted in the observatory in 1896. The objective lens of this telescope, as that of the Lick telescope, was made by Alvan Clark & Sons.

The lines of the mounting of the Yerkes refracting telescope follow generally those of the Lick telescope, and, like the latter, it has functioned perfectly. These two great refractors, the largest in the world, were, to a greater extent than the later telescopes, peculiarly Mr. Swasey's own design in both form and mechanism, and mark a great advance not only in accuracy and mechanical performance but in beauty and harmony of line. All of Mr. Swasey's designs, whether of machine tools, scientific instruments or telescope mountings, were characterized on the one hand by the simplest possible mechanism to achieve the desired purpose, by absence of purposeless ornamentation, by suitable strength and ruggedness where required, and on the other hand by smoothly flowing, pleasing lines, and harmony and beauty of form. Mr. Swasey was unequalled in combining engineering requirements with a real artistic sense of symmetry and proportion.

The Lick telescope completed in 1888, with an objective lens 36 inches in diameter, and the Yerkes 40-inch telescope mounted in 1896, were then, and have remained, the largest refracting telescopes in the world. The emphasis of astronomical research has since changed from visual to photographic observation in which light-gathering power is more effective than magnifying power, and because of both optical and mechanical advantages the reflecting type of telescope has been adopted for instruments of larger size. Mr. Swasey took an active part in the design of the new type of telescope.

The first large reflecting telescope constructed by the Warner & Swasey Company, having a mirror 72 inches in diameter, was for the Canadian Government Observatory, near Victoria, British Columbia. This instrument, and the covering dome and observing bridge, completed in 1916, has numerous improvements in

the mounting and operating mechanism, all designed by Mr. E. P. Burrell, Works Engineer of the company, whose untimely death preceded that of Mr. Swasey by only four months. The 72-inch mirror and the optical accessories for this telescope were made by the John A. Brashear Company, Ltd., of Pittsburgh. Dr. J. S. Plaskett, who was the Director of the Observatory for twenty years, in his memoir [3] of Mr. Swasey says:

"The beautiful lines of this mounting, unequaled in either earlier or later telescopes, and the symmetry and harmony of the design, were due to the engineering artistry of Mr. Swasey, who possessed a real genius in mechanical design with the beautiful and satisfying in appearance. This telescope set a new standard in accuracy, convenience and speed of operation, amply confirmed by the quality and quantity of the work produced in its twenty years of operation."

A mounting for a 60-inch reflecting telescope and covering dome for the Argentine National Observatory at Córdoba was completed in 1922, and a 69-inch reflector with dome was made in 1923 for the Perkins Observatory of Ohio Wesleyan University at Delaware, Ohio. The optical parts of these telescopes were provided by J. W. Fecker, successor to the John A. Brashear Company.

At the time of Mr. Swasey's death there was nearing completion an 82-inch reflecting telescope, the largest and most advanced instrument yet constructed by the Warner & Swasey Company, for the McDonald Observatory of the University of Texas, located on Mount Locke, near Fort Davis, Texas. The company carried out in its own shops the grinding and figuring of the mirror and the optical accessories of a telescope for the first time, in connection with this instrument. The well-known optician, C. A. Robert Lundin, here accomplished the most accurate parabolic mirror ever constructed. The completed mounting was erected in the shops of the company and Mr. Swasey's friends gathered around this masterpiece of mechanical design on December 19, 1935, in celebration of his eighty-ninth birthday, doing honor to him and to the men whose skill he had

[3] J. S. Plaskett, *Monthly Notices, The Royal Astronomical Society,* **98,** 258-262 (1938).

helped to develop. The casting and annealing of the glass disk was completed by the Corning Glass Works in October, 1934. The grinding and figuring of its reflecting surface at the Warner & Swasey optical shop extended over four years to October, 1938. Dr. J. S. Plaskett, retired Director of the Dominion Astrophysical Observatory, acted as scientific consultant on this project. He remarks, "It can safely be stated that the quality of the 82-inch mirror of the McDonald Observatory is unequalled by any mirror previously made and tested." [4] The formal dedication of the Observatory took place on May 5, 1939.

Mr. Swasey himself considered that his greatest achievement in the design of precision mechanism is the dividing engine for graduating circles, which was completed in 1898. This machine automatically graduates circles of any diameter up to forty inches, in degrees and minutes of arc, for use on astronomical meridian circles and transits for the determination of fundamental star places, and for instruments used in geodetic surveying. Precision is of supreme importance. The maximum error in the readings of the master circle is less than one second of arc, which ranks this engine as among the most precise of its kind in the whole world. There are 1,296,000 seconds in a complete circle; in a circle forty inches in diameter this machine does not make an error greater than 1/12000 of an inch. The graduations on the inlaid silver band of the master circle of the dividing engine are so fine that they can scarcely be seen with the naked eye, yet the width of each line is twelve times the maximum error of the angular values which the engine produces automatically. Another description of the precision is that if the circle were enlarged to a diameter of six miles, no graduation would be out of its correct position by as much as an inch. In such an engine it is essential that the spindle carrying the master plate shall accurately fit into its bearing, and that the worm gear on the circumference of the plate and the screw for rotating the plate shall be perfect. Mr. Swasey was ably assisted in the machine work by Mr. Gottlieb L. Fecker as superintendent of the

[4] J. S. Plaskett, *The Astrophysical Journal*, 89, 84-98 (1939).

Instrument Department. Professor Edward W. Morley, of Western Reserve University, carried out the calibration of the circular graduation and verified the corrections to the screw and gear of the master circle. The circles for the large meridian circle of the United States Naval Observatory at Washington were graduated on this engine, and were found to be the most precise till then made.

At the time of the conferring of the John Fritz Medal, in 1924, Major General William Crozier, former Chief of Ordnance, United States Army, said: "I may have been fortunate enough to make some contribution in the service of the Army, not the least has been . . . the military discovery of Mr. Swasey; he is an engineer whose military services are worthy to rank beside those he has rendered the civil and scientific world. The first thing of which I shall speak is the instrument officially known as the Swasey Depression Position Finder."[5] Warner and Swasey provided an instrument of this type meeting the requirement that it should show at once not only the range of a vessel at sea, but also the range and direction from each of several gun positions, variously placed. Another instrument of original design, produced under the personal direction of Mr. Swasey, is the "azimuth instrument," useful in seacoast defenses. Among the many kinds of equipment for use in the field are range finders of several types, gun-sight telescopes, commander's telescopes, telescopic musket sights, and prism binoculars. During the World War the Government required three important instruments from the company, telescopic musket sights, naval gun sights, and panoramic sights. The latter instrument is used for the direction of field artillery fire, and, during the period of greatest stress, was placed first in priority of all fire-control instruments for both the Army and the Navy. The panoramic sight was produced in a manner and on a scale so satisfactory that the Government awarded a Certificate of Merit, which was accompanied by the following citation by the Chief of Ordnance:

[5] United States Superintendent of Documents, *Document Catalogue,* Vol. 7, pages 1060-1069; Vol. 9, pages 1336-1349, 5 plates.

"For exceptionally rapid development of manufacturing methods and quantity production on a vast scale of Panoramic Sights."

Mr. Swasey traveled extensively in America and abroad; with Mrs. Swasey he made two trips around the world, westward in 1902-1903 and eastward in 1910-1911; he visited various Oriental countries in 1916; he made several trips to Europe.

On their second journey around the world Mr. and Mrs. Swasey visited China, for the second time, in January, 1911, and were impressed with the importance of religious and educational activities. At Swatow, China, he built for the Baptist Missionary Society a beautiful gateway arch and a highway leading from Swatow harbor to the mission. The gateway has been named "Swasey Arch."

In 1913, after Mrs. Swasey's death, Mr. Swasey presented a Y. M. C. A. building to Canton Christian College (now Lingnan University) as a center of religious activities; the building contains a library, auditorium, club rooms, bowling alley, and other suitable equipment.

In 1916 Mr. Swasey presented a Science Building to the University of Nanking, China, and he received an urgent invitation to be present at the dedicatory exercises to be held early in 1917. Accompanied by his intimate friend, Dr. John A. Brashear, and by Dr. John R. Freeman and his two sons, Hovey T. and John R., Jr., he sailed from Vancouver, December 1, 1916, and landed at Yokohama on December 14. They journeyed across Japan and to Korea and arrived in Seoul on December 18. On the next day they were received by the Governor of Korea and visited the Oriental palace of the earlier Kings. This occurred on the afternoon of December 19, 1916, which was Mr. Swasey's seventieth birthday. Without his knowledge an elaborate birthday dinner was arranged for the evening.[6] Several prominent men associated with the medical missionary and Y. M. C. A. work in Korea were invited.

[6] John A. Brashear, *Autobiography*, edited by W. Lucien Scaife, page 189, New York, 1924. John R. Freeman, *Mechanical Engineering*, 46, 369-370 (1924).

After the dinner a mock ceremony was arranged with pomp and splendor, using antique Oriental garments, a gorgeous robe, a royal helmet, and a sword of state, centuries old; the reincarnated King, addressing Mr. Swasey, in giving the accolade said, "Rise, Sir Ambrose, Knight of the Kindly Heart." The title thus bestowed has been approved by all who knew Mr. Swasey.

The party travelled through Korea to Northern China and to Peking. Here they visited the Great Wall, and especially the remarkable Chinese Observatory on the Inner Wall of Peking, which was established in the thirteenth century. Several very impressive astronomical instruments made in France in the seventeenth century were mounted there; at the close of the Boxer Revolution in 1900, five of the instruments were removed by the Germans to the garden of the palace at Potsdam in Germany. Mr. Swasey took an active interest in the return of these instruments to their original foundations, in accordance with provisions of the Treaty of Versailles.

The party journeyed onward, visiting Hankow and other cities, and to Nanking, arriving the day before the dedication of the Swasey Science Building, which occasion was the reason for the visit to China. This notable ceremony, which took place on January 12, 1917, is described by Dr. Brashear in his Autobiography. Eighteen congratulatory addresses were made, to which Mr. Swasey responded, expressing his pleasure in presenting the Science Building. Dr. Brashear adds: "How strange it seemed to me to have come more than ten thousand miles from home, from the universities and schools I loved so well, to a so-called benighted land, to find such a beautiful building dedicated to science, to truth-seeking among the mysteries and marvels of God's universe!" The morning after the dedication, Mr. Swasey gave a brief address in the chapel. In the evening, the alumni association of the college held a banquet and after the banquet the party left for a night trip to Shanghai. They proceeded homeward by way of Manila, Hong Kong, Canton, Japan, Hawaii and San Francisco.

In his travels Mr. Swasey had become much impressed by the romantic beauty and the legends of the Orient. Carved

ivories made an especial appeal. While crossing the Pacific Ocean in 1916 he arranged with a friend, who was a missionary stationed in Burma, to obtain a pair of elephant's tusks. Five years later an exceptionally large and beautiful pair of tusks was secured, being four and a half feet long. A carefully chosen, artistic carver in ivory was commissioned to record a mythological Buddhist story.[7] The entire surface of each tusk is exquisitely carved with a conventional design, there being twenty deep recesses, in each of which is a carved scene of the legend. There is a large teakwood base, carved to correspond with the ornamentation on the tusks, to which the tusks are attached in an upright position, by means of carved silver mountings. The artist and his assistant worked continuously for more than a year to complete this work. In accordance with his wish, after his death, these tusks were presented to the Smithsonian Institution and are now on exhibition in the Asiatic Hall of the United States National Museum.

Mr. Swasey received many formal honors, medals and degrees. In 1900 the Government of France conferred upon him the distinction of Chevalier of the Legion of Honor and in 1921 that of Officer of the Legion of Honor.

The United Engineering Societies conferred the John Fritz Gold Medal and Certificate upon Mr. Swasey on April 23, 1924; the certificate reads: "For his achievement as a designer and manufacturer of instruments and machines of precision, a builder of great telescopes, a benefactor of education, and the Founder of The Engineering Foundation." This medal is the most distinguished honor that can be awarded in the engineering profession. This medal was first awarded in 1902 to John Fritz, its founder; then to Lord Kelvin, George Westinghouse, Alexander Graham Bell, Thomas Alva Edison, and for the nineteenth award to Marconi, and to Mr. Swasey for the twentieth award.

In 1930 the Cleveland Chamber of Commerce awarded the bronze medal and certificate to Mr. Swasey, "For distinguished service to the City of Cleveland."

---

[7] Ambrose Swasey, "Carved Ivory," a booklet of 41 pages, with many illustrations Privately printed, Cleveland, 1927.

In 1932 the Franklin Institute awarded the Franklin Gold Medal and Certificate and also a Certificate of Honorary Membership in the Institute, the highest award in its power to confer. The citation reads: "In recognition of his development of methods and his invention of appliances . . . and of his scientific vision in the establishment of The Engineering Foundation for the promotion of research and its application in the various fields of engineering."

In 1933 Mr. Swasey was chosen by his fellow members of the American Society of Mechanical Engineers to receive the A. S. M. E. Medal "for distinguished service in engineering and science."

The Washington Award, a bronze tablet, was awarded in 1935 to Mr. Swasey by a commission representing The American Society of Civil Engineers, The American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, The American Institute of Electrical Engineers, and The Western Society of Engineers. The award is "In recognition of devoted, unselfish and pre-eminent service in advancing human progress."

The Hoover Gold Medal was awarded to Mr. Swasey at a dinner in his honor in connection with the annual meeting of the American Society of Mechanical Engineers in New York on December 2, 1936, a few days before his ninetieth birthday. This medal was perpetually endowed by Conrad N. Lauer, of Philadelphia, and had been awarded only once previously, in 1930, and then to Herbert C. Hoover, in honor of whom the medal is named. Mr. Hoover was present on the occasion of the award to Mr. Swasey and gave one of the principal addresses. The medal is awarded to a member of the engineering profession who, outside of and beyond professional duties, sets a high standard of leadership and performs distinguished public service. The award is determined by a joint board of representatives of the four national societies of mechanical, civil, electrical, and mining and metallurgical engineering.

On the occasion of the award of the Hoover Medal, on December 2, 1936, Mr. Swasey was presented with the Medal of Honor of the "Verein Deutscher Ingenieure" of Germany.

The citation states: "Outstanding designer of machine tools, astronomical and optical instruments, the founder of an enterprise which has gained world-wide reputation, the great benefactor of engineering research." The "enterprise" referred to is The Engineering Foundation. The citation was accompanied by a letter from the President of the German Society, stating that the presentation is in celebration of Mr. Swasey's ninetieth birthday.

When a new minor planet or "asteroid" is discovered, astronomers give it a serial number, and they also allow the discoverer the privilege of choosing a name for it. As a tribute to Mr. Swasey on his eighty-eighth birthday, December 19, 1934, Dr. Otto Struve, Director of the Yerkes Observatory, who had discovered asteroid No. 922, gave it the name "Swaseya." The *a* was added to the name in accordance with the tradition that all names of asteroids shall end with *a*.

Seven academic institutions conferred honorary degrees upon Mr. Swasey. The degree of Doctor of Engineering, D. Eng., was conferred by the Case School of Applied Science in 1905, in recognition of his contributions to engineering and science which had been manifested in the designs of the Lick and Yerkes telescopes and of the precision dividing engine for circles. In 1910 Denison University conferred the Doctorate in Science, D. Sc., and in 1924 the University of Pennsylvania gave the same degree. The degree of Doctor of Laws, LL.D., was conferred by the University of California in 1925, by the University of Rochester in 1925, and by the University of New Hampshire in 1930. In 1931 Brown University awarded him the degree of Doctor of Science, D.Sc.

The wide scope of the activities in which Mr. Swasey was interested and the esteem of his associates is manifested by the large number of learned and scientific societies of which he was a member. The more important of these societies, with the dates of election and mention of official positions are the following. The National Academy of Sciences, 1922; the American Philosophical Society, 1919; the American Astronomical Society, 1918; the National Research Council, 1916, Patron; the American Association for the Advancement of Sci-

ence, Fellow, 1934; American Society of Mechanical Engineers, Charter Member, 1880, Vice President, 1900-1902, President, 1904, Honorary Member, 1916; American Society of Civil Engineers, Honorary Member, 1921; American Institute of Electrical Engineers, Honorary Member, 1928; Cleveland Engineering Society, 1882, President, 1894, Honorary Member, 1917; the Franklin Institute, Honorary Member and Medalist, 1932; New Hampshire Society of the Cincinnati, 1908, Honorary Member, 1919.

Mr. Swasey was elected a member of the British Astronomical Association, a society of active amateur astronomers, in 1897; in 1898 he was made a Fellow of the Royal Astronomical Society. He became a member of the Institute of Mechanical Engineers of Great Britain in 1898, and received Honorary Membership in 1921; in 1921 he was elected to Honorary Membership in the Institute of Mining Engineers of Great Britain. In 1921 the Société des Ingenieurs Civils de France bestowed Honorary Membership.

Mr. Swasey's list of honors is rivalled, indeed is exceeded, by the catalogue of his benefactions to religious organizations, to education, and to engineering and science. In the funeral oration at Exeter it was related that his first experience in giving was to go into the woods with his brother, there to chop two cords of wood and haul it to the Baptist parsonage. He was very modest and unostentatious regarding his philanthropies, and only those of a necessarily public nature are known. Reference has already been made to his gifts in China, the Highway and Gateway to Swatow, the Y. M. C. A. building at Canton, the Science Building at Nanking, and to the Oriental carved ivory presented to the Smithsonian Institution. Mr. Swasey made further gifts in trust of $50,000 each to the Canton Christian College and to the University of Nanking, the proceeds to be used for current expenses.

In 1899, Mr. Swasey and his partner, Mr. Warner, presented a 10½-inch refracting telescope with a revolving dome to Western Reserve University; this instrument is mounted on the building of the Laboratory of Physics.

In 1910, Mr. Swasey presented to Denison University a beautiful astronomical observatory, constructed of white Vermont marble, together with a 9-inch equatorial telescope and a 4-inch combined transit and zenith telescope. He also presented a complete file of the *Proceedings of the Royal Astronomical Society of London.*

The Warner and Swasey Observatory of Case School of Applied Science, Cleveland, Ohio, was dedicated on October 12, 1920. The observatory and the 10-inch refracting telescope are the gifts of Worcester R. Warner and Ambrose Swasey. In the presentation address Mr. Warner said in part: "This telescope and dome are the ones that we had mounted between our residences in this city for twenty-five years, but they have been remodelled and all the improvements made since they were built have been embodied in the present instruments. The optical parts are the work of John A. Brashear. This telescope made a record years ago, for we exhibited it at the Paris Exposition in 1900. There were other telescopes exhibited from Germany, England and France, but this was the only instrument that received a gold medal." Mr. Swasey said in part: "Mr. Warner and I are often asked if building telescopes is our only business and sometimes I have answered that we get our money out of machinery and our glory out of telescopes. However, while the monetary reward may have been meager we have been amply compensated for all our astronomical work by the benefits we have received from the men of science with whom we have been associated at this work."

For the perpetuation of the gracious influence and memory of Mrs. Swasey, who died in 1913, Mr. Swasey established, in 1915, the Lavinia Marston Swasey Memorial Fund of $300,000 for ministerial relief through the Northern Baptist Convention. In 1929 he contributed $100,000 to the fund for the construction of a Library Building for the Colgate-Rochester Divinity School.

In 1916 Mr. Swasey made a contribution of $52,500 to the endowment fund of Denison University, Granville, Ohio. In June, 1922, he formally offered to "provide sufficient funds to erect and equip a Chapel of ample capacity, designed and located

in conformity with the plans prepared by the architect of Denison University." The cornerstone was laid on November 4, 1922. The Chapel is an exceptionally beautiful example of the "colonial" style of architecture. The auditorium has a seating capacity of thirteen hundred persons. The gift, valued at more than $300,000, included a fine three-manual pipe organ and a memorial bell tower in memory of Mrs. Swasey, the tower containing a carillon of ten bells.

Mr. Swasey was a Trustee of the Western Reserve Historical Society of Cleveland from 1912 till his death; in 1920 he created a trust fund of $50,000 for the Society; he purchased and then presented to the Society for addition to its numismatic collection 900 Greek and Roman coins, and 1500 specimens of coins of the Chinese Empire dating back to the world's earliest metal coinage of about 800 years B.C.; he provided two especially designed steel cases for the numismatic collections.

On his eightieth birthday, December 19, 1926, Mr. Swasey sent a letter to the President of Case School of Applied Science, as follows:[8] "For many years I have been greatly interested in your institution . . . and have been especially attracted to the Department of Physics . . . because of the work in scientific research. . . . I have today set over . . . one hundred thousand dollars ($100,000) as an Endowment for a Chair of Physics. . . ."

Mr. Swasey was one of the founders of the American Society of Mechanical Engineers (1880) and served as President of the Society in 1904. For several years he considered how best to assist his fellow engineers, through his own society or some other organization, in working out problems for which till then no means had been provided. After consulting friends competent to advise, in 1914, he anonymously proffered a gift of $200,000 to the United Engineering Society. The gift was accepted and "The Engineering Foundation" was established as a department of the United Engineering Society, to administer this fund, in the words of the donor, "for the furtherance of research in science and engineering or for the advancement in any other

[8] *Science*, LXV, 9 (1927).

manner of the profession of engineering and the good of mankind." [9]

The original gift, made in 1914, was $200,000; to this Mr. Swasey added $100,000 in 1918, $200,000 in 1923, and $250,000 in 1931; the sum of these gifts made in his lifetime is $750,000. After his death it was disclosed that in 1923 he had begun to build up a trust fund for the further benefit of The Engineering Foundation. When this fund was delivered to the Foundation it amounted to more than $89,000, making the total of his gifts $839,000. He intended his contributions to be the nucleus of a larger endowment, to which others would contribute as the years passed.

The National Academy of Sciences took steps in 1916 toward organizing for services to our country in war and in peace a body whose membership should embrace representatives of many sciences and arts. The National Engineering Societies promptly coöperated in the creation of the National Research Council. Money was lacking with which to begin operations and the Engineering Foundation met the emergency. This was the Foundation's first notable undertaking, and it has continued to the present time its relationships with the Council.

The founder societies in 1919 assisted the National Research Council in establishing its Division of Engineering and Industrial Research in the after-war reorganization. Some members of the Board of the Engineering Foundation are also members of the Division of the National Research Council. The Foundation has provided offices for the Division in the Engineering Societies Building, New York, since May 1, 1919, and has coöperated with the Council in a number of research projects, including organization of Advisory Board on Highway Research, American Bureau of Welding and Personnel Research Federation; fatigue (endurance) of metals, marine piling, molding sands for foundries, pulverizing of ores, cements and fuels, heat transfer and electrical insulation; also compiling a directory of research laboratories in the industries of the United States.

[9] Alfred D. Flinn, *Science*, 78, 424-428 (1933). The Engineering Foundation, *Annual Report*, 1936-1937, pages 12, 13, 20, 21, *et seq.* The Engineering Foundation, Otis Ellis Hovey, *Twenty-Five Years of Service*, 1914-1939, 85 pages, New York, 1940.

Betterment of engineering education has been promoted through assistance to the Society for the Promotion of Engineering Education in investigations of institutions, methods and needs, and its summer schools for engineering teachers.

The adequate development of the work of the National Academy of Sciences and the National Research Council required a building in Washington with proper facilities and of architectural impressiveness. An entire city block facing the Mall near the Lincoln Memorial was selected for the site, and funds for the purchase of the land were raised by subscription. Mr. Swasey contributed $10,000 for this purpose.

Mr. Swasey served the United States Government in various capacities. In 1907 he was a member of the National Board of Trade and held the office of First Vice President. In 1909 President Theodore Roosevelt appointed him a member of the Assay Commission of the Government Mints, and President Taft appointed him to the same commission in 1913. From 1921 to 1926 he served on the Board of Visitors of the National Bureau of Standards; he took an active part in the selection of a Director of the Bureau in 1923. As a representative of the United Engineering Society and the Engineering Foundation he participated in the organization of the National Research Council in 1916 and was a member of its Division of Engineering and Industrial Research till 1927; he served on various important committees and was a Member at Large of the Executive Board of the National Research Council, 1921-1927.

Mr. Swasey was a member of the Jury of Awards of four important Expositions: the Tennessee Centennial Exposition, Nashville, 1897; the Pan-American Exposition, Buffalo, 1901; the Louisiana Purchase Exposition, St. Louis, 1904; and the Jamestown Tercentennial Exposition, Jamestown, 1907, being the Vice President of the Jury.

In 1914, in celebration of one hundred years of peace between Great Britain and the United States, the British Peace Centenary Commission purchased Sulgrave Manor, a charming Tudor House, located in Northamptonshire, England, which had been the home of George Washington's ancestors, and made it a permanent memorial. The Sulgrave Institution was organized in

this country to assist in obtaining a permanent endowment of \$100,000 for the memorial. Mr. Swasey was a member of the Board of Governors and he contributed \$1000 to this fund.

The Museum of the Peaceful Arts was organized in New York in 1927, being an International Industrial Museum illustrating the progress of civilization from the earliest times to the present. Later, this museum became the New York Museum of Science and Industry. Mr. Swasey was a member of the Board of Trustees from 1927 till his death.

In 1929 Mr. Swasey was appointed a member of the National Committee for the Benjamin Franklin Building and Endowment Fund of the American Philosophical Society, and he contributed \$25,000 to this fund.

Mr. Swasey was a member of the Baptist Education Society of the State of New York from 1928 and served as its President. He was a member of the Northern Baptist Convention and served on the Executive Committee and the Finance Committee from 1922.

Mr. Swasey was a member of the Board of Trustees of Denison University, Granville, Ohio, from 1897 till his death. He was President of the Board in 1922; in 1923 he resigned this office and was made Honorary President of the Board, which honor he held till his death.

Mr. Swasey was a Trustee of Western Reserve University from 1908 to 1913 and from 1930 till his death, 1937; he was a Trustee of Adelbert College from 1926 till his death.

Mr. Swasey was elected a member of the Corporation of Case School of Applied Science in 1922; and in 1929, upon the death of Worcester R. Warner who had been a member of the Board of Trustees of Case since 1889, Mr. Swasey was elected as his successor and continued a member of the Board till his death.

Mr. Swasey was a member of the Board of Trustees of Nanking University, China, from 1924 till his death in 1937.

Mr. Swasey was prominent in civic affairs in the city of Cleveland. He was a member of the Cleveland Chamber of Commerce since 1898, and served as its President in 1905. He was a Corporate Member of the Society for Savings Bank, and

for twenty-five years a Director of the Cleveland Trust Company. He was President of the Caxton Building Company.

Mr. Swasey was a Trustee of the Cleveland Young Men's Christian Association from 1912 till 1931, and was President of the Board of Trustees in 1917 and 1918.

Mr. Swasey was a Trustee of the First Baptist Church of Cleveland and was Honorary President of the Board of Trustees from 1922 to 1937. He contributed $200,000 to the fund for the new church building in Shaker Heights.

Mr. Swasey was a Life Member and a Past President of the New England Society of Cleveland and the Western Reserve.

Mr. Swasey became a member of the well-known book-lover's club of Cleveland, the Rowfant Club, in 1896; he served on the Board of Fellowes for the terms 1901-1904 and 1908-1914; he was President of the Club in the year 1912-1913. Mr. Swasey presented the Club with a medal in honor of John Hay; the medal was designed and executed by Victor David Brenner and one hundred and seventy exemplars were struck at the United States Mint in 1912, one exemplar being presented to each member of the Club.

Mr. Swasey and Mr. Warner appreciated the value of their apprenticeship training and resolved to offer greater opportunities in their own shops. In 1911 an Apprenticeship School was established under the direction of a regular Apprentice Instructor. Besides organized shop work the apprentice receives four hours each week of classroom instruction in subjects of direct practical value. For advanced and related subjects, the apprentice is urged to attend one of several available night schools. Through his official connection for many years with the Cleveland Young Men's Christian Association, Mr. Swasey was able to provide exceptional opportunities to especially deserving young men of high character and ability. Many of these apprentice graduates have come to positions of leadership and influence.

Mr. Swasey was a member of various clubs, among which are the Cosmos Club of Washington, the Union League Club, the Engineers' Club and the Grolier Club of New York, and the

Union Club of Cleveland; of the latter club he was a Director and he served as President for two terms.

Two and a half years after he became associated with the Pratt and Whitney Company, when he was nearly twenty-five years old, Mr. Swasey was married on October 24, 1871, to Lavinia Dearborn Marston, daughter of David Marston of Hampton, New Hampshire. Mrs. Swasey was reserved in manner, gracious, and deeply religious; she contributed in a large measure to his happiness and success. There were no children. Mrs. Swasey died on January 22, 1913. Mr. Swasey left a fund of $30,000 in trust for the Congregational Church of Hampton, New Hampshire, in memory of Mrs. Swasey's mother.

The fine old farm, about a mile north of the town of Exeter, in New Hampshire, upon which Mr. Swasey's grandfather lived to the good old age of ninety-four years, and where his father spent his long life from 1800 to 1890, came into Mr. Swasey's possession, and he often went back to the old homestead where he spent the happy days of his childhood and youth. The old home was modernized on a modest scale and in excellent taste in 1903, and was occupied as a summer residence. Here Mr. Swasey died on June 15, 1937.[10]

On the western part of this estate there are two massive boulders rising to a height of ten feet, with flat surfaces on their adjacent sides, which have been used as an immense fireplace. This quaint upheaval of nature, in the early period of the town, was a resort for Indians, and later for vagabonds. In 1697 a party of Indians used the rocks as a "fort" from which to attack the town, and the name of "Fort Rock" has persisted. Mr. Swasey adopted the name "Fort Rock Farm" for his homestead and used this title on his stationery.

---

[10] Immediately after Mr. Swasey's death the following biographical articles appeared: W. W. Campbell, "Ambrose Swasey, 1846-1937," *Publications of the Astronomical Society of the Pacific*, **49**, 179-185 (1937). Portrait. J. J. Nassau, "Ambrose Swasey, Builder of Machines, Telescopes and Men," *Popular Astronomy*, **45**, 407-418 (1937). Portrait, 6 illustrations; *Journal of Applied Physics*, **8**, 595-601 (1937). J. S. Plaskett, "Ambrose Swasey, Engineer, Scientist, Philanthropist," *Journal of the Royal Astronomical Society of Canada*, December, 1937, pages 409-416. Portrait. "Obituary Notice of Ambrose Swasey," *Monthly Notices of the Royal Astronomical Society*, **98**, 258-262 (1938).

Mr. Swasey was always deeply interested in the welfare of his native town of Exeter, a small city of about 5000 inhabitants, located in the southeastern corner of New Hampshire on the Exeter River, about thirteen miles southwest of the seaport, Portsmouth. He gave $50,000 to the endowment fund of the local hospital, and $25,000 to the Baptist Church of Exeter. He made further gifts to the church: the sum of $5000, a pipe organ which he did not live to hear played, and two memorial windows. In 1916 he presented a pavilion, located in the public square in the center of the town. The pavilion is an architectural gem of great beauty, designed by the eminent architect, Henry Bacon, of New York. It is constructed of pink Milford granite and white marble, with eight marble columns supporting the copper roof. There is a bronze plate with the signs of the zodiac, and a bronze chandelier, and bronze railings and gate. The pavilion may be used for public speaking and for band concerts. The gift also includes a granite watering trough set at one side of the Square. He gave $11,500 to the New Hampshire Society of the Cincinnati for the purchase of property for its "home" at Exeter.

Mr. Swasey caused to be filled in and beautified a strip of swampland, several hundred feet wide, on the right bank of the Exeter River (formerly called the Squamscott River), extending from the business center of Exeter, northerly about a mile to the old homestead, Fort Rock Farm. This has been named "The Swasey Parkway."

Mr. Swasey's active mind and optimistic spirit together with an unusually robust constitution enabled him to maintain a keenly intellectual and bodily activity until the end. In the summer of 1936 he visited his scientific friends in England. On the occasion of the presentation of the Hoover Medal in New York on December 2, 1936, a few days before his ninetieth birthday, he took his full part in the ceremonies, including a brief speech expressing his thanks and appreciation for the honors bestowed upon him, and voicing the hope that the services rendered to humanity by the engineering profession would be enlarged in scope with the passing of time. In April, 1937, he attended the meetings of the National Academy of

Sciences in Washington, an annual event which gave him great pleasure, where his friends, who enjoyed the privilege no less, greeted him with rare affection. Four weeks later he was confined to his home in Cleveland by a cold; upon his insistent request, on June 9, he was taken to his ancestral home, Fort Rock Farm, in Exeter, New Hampshire, where he died from pneumonia on June 15, 1937, aged 90 years, 5 months, and 26 days. The body was brought to Cleveland for funeral services held in the First Baptist Church on June 18; the body was returned to Exeter where services were held on June 19 in the Baptist Church, and interment took place in the Exeter Cemetery where are buried the members of his family.

The conclusion of an address by Mr. Swasey before the Franklin Institute following the presentation of the Franklin Medal, in May, 1932, expresses his oft-repeated sentiments. "Man is never satisfied in his quest for knowledge . . . now turns to far distant galaxies. . . . May we not feel that the Creator of all things so fashioned the heavenly bodies and so directed their movements, that men of science might have opportunities for study. . . . As the astronomer reaches out and out into the galaxies of the heavens, and the physicist and geologist delve deeper and deeper into the mysteries of the earth, the words of the Psalmist come to us with increasing significance, 'The Heavens declare the Glory of God and the firmament showeth his handiwork.'"

## BIBLIOGRAPHY

### Ambrose Swasey

"The Eiffel Tower from Foundation to Lantern," 7 figs. *Journal, Association of Engineering Societies,* 9. 411-426 (1890).

"A New Process for Generating and Cutting the Teeth of Spur Wheels," *Transactions, American Society of Mechanical Engineers,* 12, 265-274 (1890).

"The Specialist in Engineering," (Address of Retiring President of the Civil Engineers' Club of Cleveland) *Journal, Association of Engineering Societies,* 14, Proceedings, March, 1895, pp. 58-61 (1895).

"Some Refinements of Mechanical Science" (Address of Retiring President, December 6, 1904), *Transactions, American Society of Mechanical Engineers,* 26, No. 1052, pp 44-55 (1904-1905); Smithsonian Institution Annual Report for 1905, pp. 141-150 (1906). *Scientific American,* Supplement, 59, 24290-24291 (1905).

"Presentation Address at the Dedication of the Warner and Swasey Observatory of Case School of Applied Science," October 12, 1920. *Publication, Case School of Applied Science,* Cleveland, 1920, pp. 11-15.

"Carved Ivory," privately printed, Cleveland, Ohio, 1927, 41 pp. Illustrations, Brochure.

"Astronomers and Their Telescopes," address at the Medal Meeting of the Franklin Institute, May 18, 1932. *Journal, Franklin Institute,* 214, 265-274 (1932).

## LIST OF PATENTS

### Ambrose Swasey

165,519. Protractor—July 13, 1875.

168,354. Water Meter—October 5, 1875.

306,197. Running gear for revolving domes—October 7, 1884. (Warner and Swasey).

585,894. Feed mechanism for screw-machines—July 6, 1897. (Swasey and Lucas).

632,905. Turret lathe—September 12, 1899. (Swasey and Lucas).

632,906. Turret operating mechanism—September 12, 1899.

633,925. Friction Clutch—September 26, 1899. (Swasey and Allen).

642,884. Roller-Feed for screw-machine—February 6, 1900. (Swasey and Lucas).

642,885. Roller-Feed for screw machine—February 6, 1900.

670,213. Lathe-Chuck—March 19, 1901.

677,288. Telescopic gun sight—June 25, 1901.

737,794. Depression range-finder—September 1, 1903.

812,464. Optical instrument—February 13, 1906. (Swasey and Fecker).

815,657. Panorama-Sight—March 20, 1906.

819,948. Optical instrument—May 8, 1906. (Swasey and Fecker).
820,998. Telescopic sight for firearms—May 22, 1906.
851,706. Depression range-finder—April 30, 1907.
861,331. Horizontal range-finder—July 30, 1907.
862,293. Telescope—August 6, 1907.
862,294. Range-Finder—August 6, 1907.
906,751. Sight device for firearms—December 15, 1908.
959,179. Telescope—May 24, 1910.
964,709. Sight for firearms—July 19, 1910.

Calvin B. Bridges

NATIONAL ACADEMY OF SCIENCES

OF THE UNITED STATES OF AMERICA

BIOGRAPHICAL MEMOIRS

VOLUME XXII—SECOND MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# CALVIN BLACKMAN BRIDGES

1889–1938

BY

T. H. MORGAN

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1940

# CALVIN BLACKMAN BRIDGES

## 1889–1938

BY T. H. MORGAN

Calvin Blackman Bridges was born in Schuyler Falls, New York, on January 11, 1889, and died in Los Angeles, December 27, 1938. His father, Leonard Victor Bridges, who was brought up on a small farm near Plattsburg, married Charlotte Amelia Blackman in 1887, and Calvin was their only child.

His mother died when Calvin was two years old. His father died a year later. The Grandmother Bridges had already brought up a large family but considered it her duty to take charge of Calvin. He went to a small district school when it was convenient. When he was about 14 years old his grandmother insisted that he should be "educated," and he was allowed to go to Plattsburg. He was not ready for high school and had to spend two preliminary years in grammar school. He graduated from high school in 1909 when he was 20 years old. He had made a fine record. During the years at Plattsburg he drove to school part of the time with neighbors and worked and lived much of the time in town. He worked as "printer's devil" on the Plattsburg Press, and it was said "there is a boy who is going to amount to something." When he had spare time he was always at his books, but he was a "regular boy," good-natured and obliging.

One summer during his high school years he worked on a geological survey of Valcour Island with Professor George H. Hudson of the Plattsburg Normal School. There is extant a letter by Professor Hudson written when Calvin applied for a scholarship at Columbia University in which he says: "He is in many respects a very remarkable young man. He has always kept on the honor roll of his school and yet read very extensively outside of the lines of his school work." The list of the books he read, in Calvin's handwriting, exists and it certainly covers a very wide range of subjects. Hudson also says: "He has the questioning mind, is apt in the forming of hypotheses

and quick to see when they are weak. His great desire is to undertake research work."

At the end of his high school work Calvin was urged to try the regional examination for a four year scholarship at Cornell which he passed. He also took an examination for a one year scholarship at Columbia University and passed this also. Wishing to live near his aunt, Mrs. Billings, who lived in New Jersey, he accepted the Columbia scholarship. During his three years at college he received some aid from scholarships, but earned much of his living in other ways During one of the summers he tutored two young boys and during another he went "on the road" to sell a book entitled "Standard Dictionary of Facts."

My first contact with Bridges was in 1909 when he took a course I gave in general biology and another in embryology (1910); and later, as a graduate student, a course in experimental zoology, largely devoted to genetics, and another course in experimental embryology. He attended also Professor E. B. Wilson's course on The Cell.

Bridges graduated (B.S.) from Columbia College in 1912. In the same year he married Gertrude F. Ives, and was survived by his wife and three children, Philip, Betsey and Nathan. From 1910 to 1915 he served as part-time assistant in my work on Drosophila. In the course of this work (Morgan and Bridges 1913) certain exceptions turned up that Bridges began to study intensively. In 1913 he published briefly his results under the title of "Non-Disjunction of the Sex Chromosomes of Drosophila". A much more extended paper appeared in 1916 entitled "Non-Disjunction as Proof of the Chromosome Theory of Heredity". This work, offered as his doctoral dissertation at Columbia University, included not only genetic evidence but corresponding evidence from a study of the chromosomes that tallied with the genetic results. This paper went far towards convincing skeptics and conservatives that chromosomes are the bearers of genetic factors. It is true there was abundant evidence before 1916 showing that chromosome behavior furnishes an interpretation of heredity. It is today hard to believe that it was nearly ten years before this relation was generally accepted.

Sex-linked inheritance, as connecting genetic interpretation with known transmission of the sex chromosomes, had been established since 1910. The interpretation of crossing over, supported by less certain cytological evidence, had also been advanced in 1910, and covered what seemed to be exceptions to Mendel's laws. Crossing over opened up a new field of research in inheritance, and for 30 years formed the basis on which much of Bridges' work rested. He greatly improved the technique of locating the genes, and in the course of the following years he so thoroughly built up the genetic maps that these stand today as the most complete data we have on the location of the genes in the chromosomes.

In 1915 I received a grant from the Carnegie Institution of Washington to carry on investigations in heredity. Bridges and Sturtevant were appointed to undertake independent research work. For twelve years we three worked together in a small room in the Zoological Department of Columbia University. As the work on Drosophila ampelophila (as the vinegar fly was then called) became widely known, a succession of international fellows joined us, as well as some of the more advanced graduate students and fellows of Columbia University. It was not unusual for six of us to carry on in this small room; the only space at our disposal. Those were the days when bananas were used as fly food and in one corner of the room a bunch of bananas was generally on hand—an adjunct to our researches which interested other members of the laboratory in a different way. As there were no incubators, a bookcase and a wall case were rigged up with electric bulbs and a cheap thermostat, which behaved badly at times, with consequent loss of cultures. The use of milk bottles came into the program at an early date, but where they came from was not known, or at least not mentioned. At a later date we were bold enough to ask for a case of new bottles.

This picture of the conditions under which we worked is not intended to suggest that we were handicapped. On the contrary, our proximity to each other led to cooperation in everything that went on. The discovery of a new mutant was immediately announced, and its location in the gene chain anxiously awaited.

The Carnegie group worked at Columbia University until 1928, and from 1928 to 1938 at the California Institute of Technology. The annual grants from the Carnegie Institution of Washington contributed greatly towards the success of the genetic work on Drosophila.

The improvements that have gradually evolved have been to a large extent the outcome of Bridges' unusual inventive faculty. The hand lens was replaced by a binocular microscope of his designing; the wall cases have been supplemented by incubators with fans and expensive regulators; the banana has given place to a synthetic medium consisting of agar agar, corn-meal, molasses, and yeast. Even the symbols by which the Drosophila mutant races were named are in large part attributable to Bridges' interest in a suitable nomenclature. I recall one instance in which invention went too far. In order to save space in the incubators Bridges drew a plan for a milk bottle with a square base. But they were so closely packed that when the room temperature approached the lethal degree, the heat generated in the bottles went over the top. Unwilling to give up the new bottles Bridges got a large auger and bored holes through the carefully prepared insulated walls of the incubator.

Bridges had his own system of bookkeeping. The data were often filed on bits of scrap paper, but it was almost uncanny to see how quickly he could find any information that was called for. He has left hundreds of cards, carefully filed, which contain all the data collected in this laboratory relating to each mutant or aberration. Many of these data have never been published, and it is doubtful now if anyone will ever assemble them for publication. These data were used, however, in the calculation of loci and description of mutants and aberrations, in DIS 9, which appeared shortly after Bridges' death. This issue of Drosophila Information Service was one of the last things on which Bridges worked, and in it, fortunately, he brought down to date practically all his work in statistical genetics.

In 1916 Bridges and I brought together the then known data on the mutants and linkage relations of the first or X chromosome of Drosophila, in 1919 those of the second chromosome

were published, and in 1923 we published the data which had accumulated on the third chromosome group of mutants. Later (1935) Bridges gave a complete account up to date of the fourth chromosome (*Journal of Biology*, Moscow, U.S.S.R.).

The first gynandromorph of Drosophila was discovered in 1910. From that time onward such exceptions were watched for and recorded. In time Bridges and I had a considerable number on hand which we described in a Carnegie Publication in 1919. Bridges reported (1939) that we had at that time studied "about 100 gynandromorphs and found that the maternal X was eliminated about as often as the paternal X. In experiments in which all flies were counted 40 gynandromorphs occurred in 88,000 flies." In addition to our explanation of elimination of one of the X chromosomes, during early development, a few other exceptions were found that called for a different explanation; namely, the presence of two separate nuclei and reduction products in the egg.

Later, Bridges discussed a few individuals showing spots on the body which, from genetic evidence, were composed of haploid cells, and, in some of these mosaics, the regions included body parts that enabled one to diagnose their sex. The spots were clearly female in constitution, and this was surprising at the time since in other insects, where haploid individuals were known (bees, etc.), they were males. Bridges' finding in Drosophila was, however, consistent with the female sex formula: two X plus two sets of autosomes. In the spots the same balance is present, that is one X and one set of autosomes, so that the haploid somatic tissue is female.

During the years 1921-1925 Bridges made an extensive study of certain types of intersexes in Drosophila. He showed clearly by cytological analyses that they were due to chromosome aberrations of a type that had not been established previously for intersexes of other insects. The intersexes showed complex mixtures of male and female parts. In the first culture in which they were found (1920) there were 37 of them in addition to 9 regular males and 96 females. They were completely sterile, but certain of their sisters, when bred, gave intersexes and were shown by genetic and cytological evidence to be triploid (3N)

females. The breeding experiments with such females showed that a certain proportion of their mature eggs contained one full set of chromosomes, one X and one of each autosome, and, in addition, part or all of one extra set. Those mature eggs that contained a diploid set of chromosomes, would, if fertilized by a normal X-bearing sperm, again give 3N females, and if fertilized by a Y sperm would give intersexes. The formula for the intersexes is $3A + 2X + Y$. They differ from standard females only in having an extra set of autosomes, and this fact, as Bridges points out, "proved that autosomes (A) are as much determiners of the normal sex differences as are the so-called sex chromosomes. Autosomes turn the scale toward maleness." This idea of genic balance he had already developed in 1921 in connection with changes induced by loss or gain of a fourth chromosome. The theory was applied to the interpretation of certain other abnormal-appearing types of individuals, notably superfemales and supermales. A superfemale, he showed, arises when an individual has three X chromosomes and two autosomes. A supermale arises when one X and three sets of autosomes are present. Three types of females may exist in which the balance between X's and autosomes is the same as in the normal ($2X + 2A$) female, namely $3X + 3A$ and $4X + 4A$, besides the normal. These conclusions of Bridges were not theoretical speculations, but in every case the interpretation rested on genetic evidence, and in triploids and diploids on a cytological demonstration of the presence in the individual in question of the constellation of the chromosomes that was postulated.

Bridges paid a great deal of attention to the problem of genic balance, pointing out that it is fundamental for an understanding not only of the balance concerning sex, but for all other characters as well. The fact is that today there is demonstrable evidence that there is not a single gene for femaleness and another for maleness, but several, perhaps many, genes distributed through the chromosomes and affecting the development of certain characters in one way or in the opposite way. This conception in its broadest aspects has always been insisted on by the group working on the genetics of Drosophila, although it is also true that a change in a single gene often leads to strik-

ing changes in the individuals containing such a mutant gene. They argued that both the old and the new gene influence the end result, not by acting alone but by collaborating with other genes, and, in the last analysis, with all or most of the genes to different degrees. Each gene is thought of as a differential.

Bridges' early discovery (1917) that certain genetic data could be interpreted as due to deficiencies in the chromosome construction has led in recent years to a factual demonstration of such deficiencies. In some of his latest work (1937-1938) he made use of this discovery in the interpretation of overlapping deficiencies in analyzing the characteristics of certain mutant types. It would be hard to find in the history of genetic research a more convincing demonstration of the combination of actual evidence and masterly interpretation of it. As early as 1919 Bridges described "duplication" as a chromosomal aberration, and here, as in his other work, his conclusions rested not on vague hypotheses but on experimental proof. Much later he also reported the occurrence of "repeats" in the normal chromosome which will have to be seriously considered in future interpretations of certain types of genetic behavior.

The many interesting problems connected with losses (deficiencies) and additions (duplications) of groups of genes present interesting problems in which genic balance is involved, and the possibility, that now exists, of detecting deficiencies and duplications in the salivary chromosomes and correlating the observations with the genetic location of mutant genes is well under way, and during the last two years of his life, was receiving Bridges' close attention.

In 1925 the data, that had been collected in the course of genetic experiments, was brought together under the title "The Genetics of Drosophila," by T. H. Morgan, C. B. Bridges, A. H. Sturtevant. Not until 1934, when the first number of Drosophila Information Service edited by Bridges and Demerec appeared, was a similar summary made. Bridges spent a tremendous amount of hard work in summarizing the data, particularly those of the stocks that the Carnegie group had built up at Pasadena, and the reports include also much unpublished data that Bridges himself had on hand. Fourteen numbers of

Drosophila Information Service have appeared, the latest in February 1941.

In recent years Bridges spent much time in correlating the loci of the genetic maps with the bands of the salivary maps. He made an elaborate study of the salivary chromosomes, and more than doubled the previously known number of bands. His maps have become the standard ones for Drosophila melanogaster. As I have pointed out elsewhere, the identification of the salivary bands with the loci on the genetic map would not have been possible were it not that during the preceding twenty-three years the genetic (crossover) maps had been built up to a point where such comparisons have a real demonstrable basis. While many workers had contributed to bring the genetic maps to their status of 1933, it was Bridges in particular who had made a more detailed and critical study of the maps than had any other one of his contemporaries. His maps are now standard all over the world. During the year 1938, Bridges continued the revision of the maps of the salivary chromosomes; that of the X-chromosome has been published in the Journal of Heredity, January 1938. During the summer of 1938 he nearly finished the right half of the second chromosome in collaboration with his son Philip, who has now put it into shape for publication. He intended to leave the left half of that chromosome until the revision had extended to the other chromosomes because he had found that this half probably contains a number of "repeats", i.e., sections of duplicating parts. This idea is the last of the many new contributions that Bridges made to the "higher Mendelism" and may prove of unusual interest in the future development of genetics.

The original discovery of the banded nature of the giant salivary chromosomes of diptera goes back to Balbiani's record of 1881. But the regularity of the sequences of the bands, the union of homologous chromosomes in pairs, and distinction of regions that stain and those that do not stain was reported in 1933 by Heitz and Bauer.

Painter, also in 1933, using Drosophila melanogaster material, contributed the all-important proof that there is a close correspondence between the sequence of the banding of the chromo-

some and the sequence of the genes as determined by genetic theory and practice. Without the already existing information as to the position of the genes in definite chromosomes it would have been impossible to establish this relationship, although Painter and Muller had already in 1929 laid the basis for comparisons of this kind by demonstrating that certain genetic translocations could be visibly detected as such in the chromosomes involved in such transfers.

It became increasingly important after Painter's comparisons between the genetic and the salivary maps that identification of the bands be extended to the limit of microscopic vision in order to determine more definitely the relation of individual bands to the loci of the genes, since the determination of the correspondence between the sequence of the genes and that of the bands does not tell us whether there is an identity between them. Most of the bands are faint ones while some of the darker bands are double, etc. For this kind of work Bridges was eminently fitted. His eyesight was unusually acute but he did not depend on this alone and spent much time in the study of the best methods of illumination, and the most suitable staining and preserving technique to bring out the fainter bands. As a result his new maps more than double the number of the previously known visible bands. He was also interested in the problem as to whether the stretching of the chromosome, when the nucleus is burst under pressure, may introduce artifacts. It is unfortunate that he died when in the midst of this detective work, but his methods will enable others to take up the story where he left off.

As a member of the Carnegie group each year's progress was reported in the Year Book of the Carnegie Institution of Washington. These twenty-three reports give in briefest summary the results that Bridges had obtained. Whether the elaborate data on which these reports rested, can ever be fully utilized is questionable; but Bridges accomplished so much other work, that these will not be needed to place him amongst the leading geneticists of his time.

Bridges was a very friendly person. He was simple and unaffected and always helpful to anyone who came to him for

advice. In the course of twenty years he was largely instrumental in building up stocks of Drosophila in which mutant genes of each chromosome are spaced so that they can be used as markers for each chromosome. These stocks are especially useful in studying crossing over, translocation and other special problems. More than 900 separate stocks are carried at present. Many of them have been distributed to investigators all over the world. Bridges spent much thought and time in building up this material and distributed it freely without even claiming credit from others for its use. In fact, one of his most admirable traits was his freedom from priority claims of any kind. His death was a serious loss to genetics and to his many friends.

## BIBLIOGRAPHY

### KEY TO ABBREVIATIONS

Amer. Nat. = American Naturalist.
Anat. Rec. = Anatomical Record.
Arch. Entw.-mech. = Archiv fur Entwicklungsmechanik der Organismen.
Biol. Bull. = Biological Bulletin.
Biol. Zentral. = Biologisches Zentralblatt.
Bull. Inst. Gen. = Bulletin, Institute of Genetics, Academy of Sciences, U. S. S. R.
Carnegie Inst. Wash. Publ. = Carnegie Institution of Washington, Publications.
Carnegie Inst. Wash. Yr. Book = Carnegie Institution of Washington, Year Book.
Jour. Biol. (Moscow) = Journal of Biology (Moscow).
Jour. Exp Zool = Journal of Experimental Zoology.
Jour. Franklin Inst. = Journal of Franklin Institute.
Jour. Gen. Physiol. = Journal of General Physiology.
Jour. Heredity = Journal of Heredity.
Peking Nat. Hist. Bull. = Peking Natural History Bulletin.
Proc. Birth Con. Cong. = Proceedings, Birth Control Congress.
Proc. Nat. Acad. Sci. = Proceedings, National Academy of Sciences.
Proc. 6th Int. Cong. Genetics = Proceedings, Sixth International Congress of Genetics.
Proc. Soc. Exp. Biol. Med. = Proceedings of the Society for Experimental Biology and Medicine.
Trans. Dyn. Develop. = Transactions on the Dynamics of Development.
Zeit. Abst. Vererb. = Zeitschrift fur Induktive Abstammungs und Vererbungslehre.

*1913*

Partial sex-linkage in the pigeon. *Science*, n. s. 37: 112-113.

Non-disjunction of the sex chromosomes of Drosophila. *Jour. Exp. Zoöl.*, 15: 587-606.

Dilution effects and bicorlorism in certain eye colors of Drosophila. (With T. H. Morgan.) *Jour. Exp. Zoöl.*, 15: 429-466.

*1914*

Direct proof through non-disjunction that the sex-linked genes of Drosophila are borne by the X-chromosome. *Science*, n. s. 40: 107-109.

The chromosome hypothesis of linkage applied to cases in sweet peas and primula. *Amer. Nat.*, 48: 524-534.

A new gene in the second chromosome of Drosophila and some considerations on differential viability. (With A. H. Sturtevant.) *Biol. Bull.*, 26: 205-212.

*1915*

A linkage variation in Drosophila. *Jour. Exp. Zoöl.*, 19: 1-21.

The Mechanism of Mendelian Heredity. (With T. H. Morgan, A. H. Sturtevant, and H. J. Muller.) New York, 262 pp.

*1916*

Non-disjunction as proof of the chromosome theory of heredity. *Genetics*, 1: 1-52, 107-163.

Sex-linked inheritance in Drosophila. (With T. H. Morgan.) *Carnegie Inst. Wash. Publ.*, 237: 87 pp.

*1917*

The elimination of males in alternate generations of sex-controlled lines. *Anat Rec.*, 11: 504.

An intrinsic difficulty for the variable force hypothesis of crossing over. *Amer. Nat.*, 51: 370-373.

Deficiency. *Genetics*, 2: 445-465.

Incompatibility of mutant races in Drosophila. (With C. W. Metz.) *Proc. Nat. Acad. Sci.*, 3: 673-678.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 15: 343.

*1918*

Maroon—a recurrent mutation in Drosophila. *Proc. Nat. Acad. Sci.*, 4: 316-318.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 16: 290-291.

*1919*

Duplication. *Anat. Rec.*, 15: 357.

The genetics of purple eye color in Drosophila melanogaster. *Jour. Exp. Zoöl.*, 28: 265-305.

Specific modifiers of eosin eye color in Drosophila melanogaster. *Jour. Exp. Zoöl.*, 28: 337-384.

Vermilion-deficiency. *Jour. Gen. Physiol.*, 1: 645-656.

The developmental stages at which mutations occur in the germ tract. *Proc. Soc. Exp. Biol. Med.*, 17: 1-2.

The inheritance of the mutant character "vortex". (With O. L. Mohr.) *Genetics*, 4: 283-306.

The second-chromosome group of mutant characters. (With T. H. Morgan.) *Carnegie Inst. Wash. Publ.*, 278: 123-304.

The origin of gynandromorphs. (With T. H. Morgan.) *Carnegie Inst. Wash. Publ.*, 278: 1-122.

The construction of chromosome maps. (With T. H. Morgan.) *Proc. Soc. Exp. Biol. Med.*, 16: 96-97.
The inheritance of a fluctuating character. (With T. H. Morgan.) *Jour. Gen. Physiol.*, 1: 639-643.
The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 17: 277-278.
The spatial relations of genes. (With A. H. Sturtevant and T. H. Morgan.) *Proc. Nat. Acad. Sci.*, 5: 168-173.

*1920*

White-ocelli—an example of a "slight" mutant character with normal variability. *Biol. Bull.*, 38: 231-236.
The mutant crossveinless in Drosophila melanogaster. *Proc. Nat. Acad. Sci.*, 6: 660-663.
The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 18: 324-325.
The evidence for the linear order of the genes. (With T. H. Morgan and A. H. Sturtevant.) *Proc. Nat. Acad. Sci.*, 6: 162-164.

*1921*

Gametic and observed ratios in Drosophila. *Amer. Nat.*, 55: 52-61.
Proof of non-disjunction for the fourth chromosome of Drosophila melanogaster. *Science*, n. s. 53: 308.
Current maps of the location of the mutant genes of Drosophila melanogaster. *Proc. Nat. Acad. Sci.*, 7: 127-132.
Genetical and cytological proof of non-disjunction of the fourth chromosome of Drosophila melanogaster. *Proc. Nat. Acad. Sci.*, 7: 186-192.
Triploid intersexes in Drosophila melanogaster. *Science*, n. s. 54: 252-254.
The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 19: 329-331.

*1922*

The origin of variations in sexual and sex-limited characters. *Amer. Nat.*, 56: 51-63.
The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 20: 375-380.

*1923*

The translocation of a section of chromosome II upon chromosome III in Drosophila. *Anat. Rec.*, 24: 426-427.
Aberrations in chromosomal materials. Eugenics, Genetics, and the Family. 1: 76-81.

The third-chromosome group of mutant characters of Drosophila melanogaster. (With T. H. Morgan) *Carnegie Inst. Wash. Publ.*, 327: 251 pp.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr Bk.*, 21: 325-328.

The Mechanism of Mendelian Heredity. Revised Edition. (With T. H. Morgan, A. H. Sturtevant and H J. Muller.) New York, 357 pp.

Laboratory Directions for an Elementary Course in Genetics. (With T. H. Morgan, A H. Sturtevant, and H. J. Muller.) New York, 16 pp.

*1924*

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 22: 283-287.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 23: 231-236.

*1925*

Sex in relation to chromosomes and genes. *Amer. Nat.*, 59: 127-137.

Elimination of chromosomes due to a mutant (Minute-n) in Drosophila melanogaster. *Proc. Nat. Acad. Sci*, 11: 701-706.

Haploidy in Drosophila melanogaster. *Proc. Nat. Acad. Sci.*, 11: 706-710.

Crossing over in the X-chromosomes of triploid females of Drosophila melanogaster. (With E. G. Anderson.) *Genetics*, 10: 418-441.

The Genetics of Drosophila. (With T. H. Morgan and A. H. Sturtevant.) *Bibliographia Genetica*, 2: 1-262.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 24: 286-288.

*1926*

The mechanism of sex-determination. *Proc. Birth Con. Cong.*, New York. p. 10.

Genetics of Sciara. Rep. of paper by C. W. Metz. "The Collecting Net," Woods Hole, Mass., 1: 7.

The multiple stock 'Xple' and its use. (With T. M. Olbrycht.) *Genetics*, 11: 41-56.

The linkage relations of a benign Tumor in Drosophila. (With M. B. Stark.) *Genetics*, 11: 249-266.

The mutants of the extreme left end of the second chromosome of Drosophila melanogaster. (With C. Stern.) *Genetics*, 11: 503-530.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, 25: 312-315.

*1927*

The relation of the age of the female to crossing over in the third chromosome of Drosophila melanogaster. *Jour. Gen. Physiol.*, **8**: 689-700.

Constrictions in the chromosomes of Drosophila melanogaster. *Biol. Zentral.*, **47**: 600-603.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **26**: 284-288.

*1928*

The chromosomes of Drosophila melanogaster. "The Collecting Net," Woods Hole, Mass., **3**: 10-11.

The behavior of mutable genes. Review. *Ibid.* **3**: 10.

Chromosome aberrations and the improvement of animal forms. *Jour. Heredity*, **19**: 349-354.

Some physicochemical aspects of life, mutation and evolution. (With Jerome Alexander.) *Anat. Rec.*, **41**: 96.

Some physicochemical aspects of life, mutation and evolution. (With J. Alexander.) Colloid Chemistry; Vol. II; Biology and Medicine. Chemical Catalogue Co., pp. 9-58.

The reproductive system of triploid intersexes in Drosophila melanogaster. (With Th. Dobzhansky.) *Amer. Nat.*, **62**: 425-434.

The giant mutation in Drosophila melanogaster: Part I; the heredity of giant. (With E. Gabritschevsky.) *Zeit. Abst. Vererb.*, **46**: 231-248.

The giant mutation in Drosophila melanogaster: Part II; Physiological aspects of the giant race; the giant 'caste'. (With E. Gabritschevsky.) *Zeit. Abst. Vererb.*, **46**: 248-284.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **27**: 330-335.

*1929*

Variation in crossing over in relation to age of female in Drosophila melanogaster. *Carnegie Inst. Wash. Publ.*, **399**: 63-89.

Deficient regions of Notches in Drosophila melanogaster. (With J. C. Li.) *Ibid.* 91-99.

Some physicochemical aspects of life, mutation and evolution. (With J. Alexander.) *Science*, **70**: 508-510.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and A. H. Sturtevant.) *Carnegie Inst. Wash. Yr. Bk.*, **28**: 338-345.

*1930*

Review of the seminar report of Dr. Huettner. "The Collecting Net," Woods Hole, Mass., **5**: 113-115.

The neutralization of the effects of deficiencies through duplications of the chromosome materials. *Ibid.*, **5**: 273-274.

Haploid Drosophila and the theory of genic balance. *Science,* 72: 405-406.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* 29: 352-359.

*1931*

El tipo mutante "pink-wing" de Drosophila melanogaster. Un problema de localizacion. English summary. "Eos," 7: 229-248.

The genetic conception of life. Address given before Academy of Science, U. S. S. R., Leningrad.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* 30: 408-415.

*1932*

The suppressors of purple. *Zeit. Abst. Vererb.,* 60: 207-218.

Apparatus and methods for Drosophila culture. *Amer. Nat.,* 66: 250-273.

Specific suppressors in Drosophila. *Proc. 6th Int. Cong. Genetics,* 2: 12-14.

The genetics of sex in Drosophila. Sex and Internal Secretions. Baltimore, Chap. III: 55-93.

Recombination and crossing-over. *Amer. Nat.,* 66, 571-574.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* 31: 303-307.

Methods for distinguishing between duplications and specific suppressors. (With Jack Schultz.) *Amer. Nat.,* 66: 323-334.

*1933*

A system of temperature control. (With Hugh H. Darby.) *Jour. Franklin Inst.,* 215: 723-730.

Culture media for Drosophila and the pH of media. I. Improvements in culture methods: the role of yeast. (With Hugh H. Darby.) *Amer. Nat.,* 67: 437-472.

The mutant "proboscipedia" in Drosophila melanogaster—a case of heredity homoosis. (With Th. Dobzhansky.) *Arch. Entw.-mech.,* 127: 575-590.

Constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* 32: 298-302.

*1934*

The test-cross—a suggested genetic term. *Jour Heredity,* 25: 18.

A gas-operated incubator for Drosophila cultures. (With J. C. Li.) *Peking Nat. Hist. Bull.,* 8: 269-272.

Constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.,* 33: 274-280.

*1935*

The mutants and linkage data of chromosome four of Drosophila melanogaster. *Jour. Biol.* (Moscow), **4**: 401-420.

Salivary chromosome maps—with a key to the banding of the chromosomes of Drosophila melanogaster. *Jour. Heredity*, **26**: 60-64

Cytological data on chromosome four of Drosophila melanogaster. *Trans Dyn. Develop.*, **10**: 463-473.

The apterous-d mutation in Drosophila melanogaster (Russian, with English summary). (With N. N. Medvedev.) *Bull. Inst. Gen.*, No. **10**: 199-209.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.*, **34**: 284-291.

*1936*

Genetical and cytological studies of a deficiency (Notopleural) in the second chromosome of Drosophila melanogaster. (With Eleanor Nichols Skoog and J. C. Li.) *Genetics*, **21**: 788-795.

Demonstrations (1) of the first translocations in Drosophila melanogaster and (2) of normal repeats in chromosomes. *Amer. Nat.*, **70**: 41.

The Bar "gene" a duplication. *Science*, **83**: 210-211.

Microscope illumination systems. "The Collecting Net," Woods Hole, Mass., **11**: 208.

An oil-retaining beveled face for high-aperture condensers. *Science*, **84**: 335-336.

Genes and chromosomes. The Teaching Biologist, Nov. 1936.

Progress in cytogenetics. "The Collecting Net," Woods Hole, Mass., **11**: 244-245.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.*, **35**: 289-297.

*1937*

The vapor method of changing reagents and of dehydration. *Stain Technology*, **12**: 51-52.

Correspondences between linkage maps and salivary chromosome structure, as illustrated in the tip of Chromosome 2R of Drosophila melanogaster. *Cytologia, Fujii Jubilee*, Vol., 745-755.

Revised data on culture media and mutant loci of Drosophila melanogaster. *Tabulae Biologicae*, **14**: 343-353.

The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash. Yr. Bk.*, **36**: 298-305.

*1938*

A revised map of the salivary gland X-chromosome of Drosophila melanogaster. *Jour. Heredity*, **29**: 11-13.

The future of genetics *Current Science,* Special number on "Genetics," Mar. 1938, 37-39.
Salivary analysis of inversion-3R-Payne in the "venation" stock of Drosophila melanogaster. (With P. N. Bridges.) *Genetics,* **23**: 111-114.
Is agglutination an explanation for the occurrence and for the chromomere-to-chromomere specificity of synapsis? (With C C. Lindegren.) *Science,* **87**: 510-511.
The constitution of the germinal material in relation to heredity. (With T. H. Morgan and Jack Schultz.) *Carnegie Inst. Wash Yr. Bk.,* **37**: 304-309.

*1939*

Cytological and genetic basis of sex. Sex and Internal Secretions Second edition. Baltimore, Chap II, 15-63
A new map of the second chromosome. A revised map of the right limb of the second chromosome of Drosophila melanogaster. (With P. N. Bridges.) *Jour. Heredity* **30**: 475-476.
The constitution of the germinal material in relation to heredity. (With T. H Morgan, Jack Schultz and Viola S. Curry.) *Carnegie Inst. Wash. Yr. Bk.,* **38**: 273-277.

Harvey Cushing

NATIONAL ACADEMY OF SCIENCES

OF THE UNITED STATES OF AMERICA

BIOGRAPHICAL MEMOIRS

VOLUME XXII—THIRD MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# HARVEY CUSHING

1869–1939

BY

W. G. MacCALLUM

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1940

# HARVEY CUSHING

## 1869–1939

BY W. G. MAC CALLUM

Harvey Cushing was born in Cleveland, Ohio, on April 8th, 1869. He came from a family of physicians, his great grandfather David Cushing (1768-1814) practiced in Cheshire, Massachusetts; his grandfather Erastus (1802-1893) was a teacher in the Berkshire Medical School, and his father, Henry Kirke Cushing (1829-1910) was a practitioner in Cleveland. He had an elder brother, Edward, who after Yale, Harvard Medical School, and the Massachusetts General Hospital, practiced medicine in Cleveland and was of great influence on Harvey, stimulating him to his career in medicine.

Harvey Cushing went to school in Cleveland and then to Yale where he received his A.B. degree in 1891. Then to the Harvard Medical School where he gained his A.M. and M.D. cum laude in 1895. From this time he served for one year in surgery in the Massachusetts General Hospital and then, in 1896, he was appointed to the house-staff in surgery under Dr. Halsted at the Johns Hopkins Hospital where he remained until 1900 as resident in surgery. In that year he went to Europe and with others attended an International Congress in Paris. This remains in my memory because, I having left in February, we had made an appointment to meet at noon on August 1st at the only place to be precisely stated, the top of the Eiffel Tower, and there we met as the gun boomed noon. From there he went to Berne and with Kocher and Kronecker began his work in experimental neurology. Later he was associated with Sherrington in Liverpool and upon his return was appointed neuro-surgeon at the Johns Hopkins Hospital.

He then left the hospital where he had so long been resident surgeon and lived next door to Dr. Osler at 3 West Franklin Street where, with his associates in that house, he was a very constant guest of the Oslers nearby. This intimate and devoted association with Osler had a great influence on his life

and stirred in him not only his enthusiasm for his medical and surgical interests but perhaps especially his love for medical history and the books and writings of the great men of all time, that lasted and grew through his life and resulted in many essays and addresses, and in his magnificent library.

On June 10th, 1902, he married Katharine Stone Crowell, of Cleveland, and later they occupied a house at 107 East Chase Street where his first child, William, was born. The family was made up later of four other children, Mary, Betsey, Henry Kirke and Barbara.

His work, concentrated largely upon neurological surgery, but with a special course in experimental surgery for which the old Hunterian Laboratory was built, went on at the Johns Hopkins Hospital until 1912 when he moved with his family to Boston to take over the appointment as Professor of Surgery at the Harvard Medical School—afterward Moseley Professor of Surgery, and as surgeon-in-chief to the Peter Bent Brigham Hospital. Living in Brookline, his work at the hospital, with the acme of his development of neuro-surgery, went on until the war began. In 1915, he spent some time with the French Army at the American Ambulance Hospital in Paris, returning to Boston after a visit to the Oslers. Later, in 1917-1919, he was with Base Hospital 5 in France and after a short time, as Senior Consultant in Neuro-surgery of the American Expeditionary Force, which was a period in which his extreme physical exertions left him more or less disabled for the rest of his life. After the war he returned to Boston and carried on with increasing enthusiasm, until in 1932, he reached the age of 63, at which, according to the hospital regulation, he must retire. Next year, in 1933, he went to Yale as Sterling Professor of Neurology, a position which he held until 1937 when this professorship terminated. But he continued to work not only on the pathological changes in the brains, from cases which he had studied, but especially too upon his great interest in the anatomical literature of the middle ages. There was a celebration by the Harvey Cushing Society of his 70th birthday on April 8th, 1939, and then, on October 7th of that year, he died of coronary occlusion after a brief illness.

The early years of his work under Dr. Halsted as resident surgeon in the Johns Hopkins Hospital brought him into contact with the use of the extremely careful technical methods in operating which were based on Dr. Halsted's study of the principles involved in asepsis and the minute attention to the avoidance of any mechanical injury to such tissues as were to be left in the body so that healing proceeded through a rapid and uninterrupted course. Concentration upon these principles impressed him deeply and characterized all his operative work throughout his life. His main thought was ever the protection of the patient in every detail.

On his return from Europe where he had undertaken some neurological work, he began his great interest in neuro-surgery to which his chief agreed that he should especially devote his energies and thus began the great contribution of his life. In addition to his studies of intra-cranial tension and of neuralgic diseases of the trigeminal nerves, with operative work on the various tumors and other disturbances of the central nervous system, he grew interested in the functional activities of the pituitary gland. Many papers resulting from his experimental studies, often with Crowe and Homans, were finally related in a Harvey Lecture in 1910 and published as a book on the Pituitary Body in 1912. His interest in this extraordinary organ which he named the master gland, continued throughout his life with several books and many papers, one condition which he described being generally known as the Cushing syndrome.

Through the next years, during his stay in Baltimore, he continued his operative' study of cerebral tumors, including their effect upon the eyes and their various relations to intracranial pressure. It was then that he carried on his most stimulating course with a limited group of students in the Hunterian Laboratory on comparative surgery, which was really experimental surgery. But at no time did his interest in various aspects of the function of the hypophysis cease, and there were nine other papers before he left for Boston, ending in a Harvey Lecture on dyspituitarism. There, from 1912 on, this interest continued with some of his students and associates

and many other papers on the hypophysis and its relations with other organs of internal secretion, appeared. Further, with L. H. Weed, there were carried on studies of the cerebrospinal fluid which were later completed brilliantly by Weed and published in a series of papers.

The war interrupted his surgical activities in Boston for some time as related in various papers, and in two books, one describing Base Hospital 5, and the other, "From a Surgeon's Journal, 1915-1918." During his great physical activity throughout these years he began to show evidence of some disabilities which proved to be due to arterial changes in the extremities which made locomotion difficult and later produced worse effects. During this time with his old devotion he made several visits to Dr. Osler in Oxford and suffered with sympathy upon the tragic death of his son, Revere. Osler's death in 1919 was the next calamity and at Lady Osler's request he wrote the remarkable "Life of Sir William Osler" which was published in 1925.

From the end of the war, after his return to Boston, he worked with incredible energy until his retirement in 1932, not only over his hospital duties, his numerous operations which with his extreme precision and tenacity of purpose involved hours of intense physical exertion, his experimental work, his protracted study of the great mass of pathological material which he had accumulated, but also his bibliophilic pursuits. It seems hardly possible that any person should have been able to survive under such mental and physical toil, especially since he suffered those great disabilities from the arteriosclerotic disorder of his legs and feet which have been mentioned.

Several large books comprising his studies of the tumors of the nervous system appeared—Tumors of Nervus Acusticus, in 1917, Classification of Gliomas (with P. Bailey), in 1926, Studies in Intracranial Physiology and Surgery, 1926, Pathological Findings in Acromegaly (with L. M. Davidoff), 1927, Tumors Arising from Blood Vessels (with P. Bailey), in 1928, Intracranial Tumors, in 1932, Pituitary Body and Hypothalamus, in 1932, and finally, a great volume on Meningiomas (with L. Eisenhardt), in 1938. These, in addition to about

150 papers and addresses published during this period, give some idea of his extraordinary concentration upon his work.

After he left Boston to assume the Sterling Professorship of Neurology at Yale he took with him the pathological material from his operated cases and continued his studies of those tumors, as is shown by the last book on the meningiomas. But his long interest in the pituitary continued and he maintained further studies involving especially the so-called pituitary basophilism which is the basis of the Cushing syndrome. With Dr. K. W. Thompson he made many experimental studies in this connection.

But his old bibliophilic enthusiasm, so long stimulated by Dr. Osler, became once more almost dominant and his collection of the books of celebrated authors grew to fill many rooms. Although he wrote about many authors, his early interest in Vesalius came once more to the fore and his collection was rich in the writings of that man. Indeed, through his last days he was hard at work upon a new essay or perhaps a book on Vesalius which was interrupted by his sudden death.

In Harvey Cushing everyone recognized a person of brilliant intellect and of great personal charm. His influence upon all who came in contact with him was deep and inspiring and especially to his students and associates this had a lasting effect upon their lives. His extreme and rigid dominance over his assistants during his operations was only part of his care for the welfare of his patients and throughout the course of their illness under his supervision his devotion to their every comfort and attention to their slightest needs for the sake of their successful recovery was part of his profound interest in their good.

His contribution to the knowledge and the advance in the study of neurosurgical conditions was very great and his name will remain as one of the greatest of the world's scientific investigators in this field, illuminated as it was by his literary and artistic interests in related fields.

Many of his associates and friends have written memorial notes since his death and his biography by Dr. J. F. Fulton will appear shortly.

## HARVEY CUSHING: VITA, DEGREES AND HONORS

Bachelor of Arts, Yale, 1891.
Doctor of Medicine, Master of Arts, Harvard, 1895.
House Officer, Massachusetts General Hospital, 1895-1896.
Resident Surgeon, Johns Hopkins Hospital, October 1897-May 1900.
Associate Professor of Surgery, Johns Hopkins Hospital and Medical School, 1903-1912.
Harvard University Medical School, Moseley Professor of Surgery, 1912-1932; Professor Emeritus, 1932-1939.
Surgeon-in-Chief, Peter Bent Brigham Hospital, 1912-1932; Surgeon-in-Chief Emeritus, 1932-1939.
Director, U. S. Army Base Hospital No. 5, 1917-1919.
Yale University, Sterling Professor of Neurology, 1933-1937; Professor Emeritus, 1937-1939.
Member, American Association of Pathologists and Bacteriologists. 1900.
Member, American Association for the Advancement of Science. 1902.
Member, American Neurological Association (President, 1923). 1903.
Member, American Physiological Society. 1905.
Fellow, American Surgical Association (President, 1927). 1906.
Fellow (Hon.), Royal College of Surgeons, England. 1913.
Fellow (Hon.), Institute of Hygiene (London). 1913.
Fellow, American College of Surgeons (President, 1922). 1913.
Member, National Academy of Sciences. 1917.
Fellow, Societas Medicorum Sverena. 1917.
Companion of the Bath (Military). 1919.
Doctor of Laws, University of Cambridge. 1920.
Chevalier, Legion d'Honneur. 1922
Doctor of Medicine (Hon.), John Casimir University, Lwow, Poland. 1926.
Pulitzer Prize in Letters, Columbia University. 1926.
Honorary Fellow, Royal Society of Medicine, London. 1927.
Doctor of Laws, University of Glasgow. 1927.
Doctor of Laws, University of Edinburgh. 1927.
Fellow (Hon.), Royal College of Surgeons, Edinburgh. 1927.
Lister Prize Medalist, Royal College of Surgeons, England. 1929.
Docteur "honoris causa," University of Strasbourg 1929, Brussels 1930, Budapest 1931.
Doctor of Medicine "honoris causa," University of Amsterdam (Tercentenary celebration). 1932.
Ehrenmitglied, Gesellschaft deutscher Neurologen und Psychiater. 1932.
Docteur "honoris causa," University of Paris. 1933.
Foreign member, Royal Society, London. 1933.
Foreign member, Royal Academy of Sciences, Sweden. 1934.
Ehrenmitglied, Gesellschaft der Chirurgen in Wien. 1936
Doctor of Science "honoris causa," Oxford. 1938.

## BIBLIOGRAPHY OF HARVEY CUSHING


### *Books and Monographs*

The pituitary body. 1912, Lippincott Co.
Tumors of nervus acusticus. 1917, W. B. Saunders Co.
Story of Base Hospital No. 5. 1919, University Press, Cambridge.
Life of Sir William Osler. 1925, Clarendon Press.
Classification of gliomas. (With P. Bailey.) 1926, Lippincott Co.
Studies in intracranial physiology and surgery. 1926, Oxford University Press.
Pathological findings in acromegaly. (With L. M. Davidoff). 1927, Monograph, Rockefeller Institute for Medical Research.
Tumors arising from blood vessels. (With P. Bailey.) 1928, C. C. Thomas.
Consecratio medici. 1928, Little, Brown and Co.
Intracranial tumours. 1932, C. C. Thomas.
Pituitary body and hypothalamus. 1932, C. C. Thomas.
From a surgeon's journal. 1936, Little, Brown and Co.
Meningiomas. (With L. Eisenhardt.) 1938, C. C. Thomas.

### *Addresses, Papers in Journals, and Reports*

*1898*

Typhoidal cholecystitis and cholelithiasis. *Johns Hopkins Hosp. Bull.*, IX, 91.
Haematomyelia from gunshot wounds of the spine. *Amer. Jour. Med. Sci.*, CXV, 654.
Operative wounds of thoracic duct. *Ann. Surg.*, XXVII, 719.
Cocaine anaesthesia in treatment of hernia and thyroid tumors. *Johns Hopkins Hosp. Bull.*, IX, 192.
Laparotomy for intestinal perforation in typhoid fever. *Ibid*, 257.
Discussion of two cases of pylorectomy by Dr. Finney, *Ibid*, 295.

*1899*

Acute diffuse gonococcus peritonitis. *Ibid*, X, 75.
Remarks upon a case of jejunal fistula. *Ibid*, 136.
Observations upon the origin of gall-bladder infections and upon the experimental formation of gall-stones. *Ibid*, 166.
Splenectomy for primary splenic anaemia. *Maryland Med. Jour.*, XLI, 140.

*1900*

Employment of local anaesthesia in the radical cure of certain cases of hernia, with a note upon the nervous anatomy of the inguinal region. *Ann. Surg.*, XXXI, 1.
Observations upon the neural anatomy of the inguinal region relative to the performance of herniotomy under local anaesthesia. *Johns Hopkins Hosp. Bull.*, II, 58.

Exploratory laparotomy under local anaesthesia for acute abdominal symptoms occurring in the course of typhoid fever. *Phila. Med. Jour.*, V, 501.

A method of total extirpation of the Gasserian ganglion for trigeminal neuralgia. *Jour. Amer. Med. Assn.*, XXXIV, 1035.

Laparotomy for intestinal perforation in typhoid fever. *Johns Hopkins Hosp. Rept.*, VIII, 209.

Experimental and surgical notes upon the bacteriology of the upper portion of the alimentary canal. (With L. E. Livingood.) *Johns Hopkins Hosp. Rept.*, IX, 543.

A comparative study of some members of a pathogenic group of bacilli of the hog cholera or bac. enteritidis (Gärtner) type, intermediate between the typhoid and colon groups. *Johns Hopkins Hosp. Bull.*, XI, 156.

Thrombosis of carotid artery. *Johns Hopkins Hosp. Bull.*, XI, 260.

*1901*

Sur la laparotomie exploratrice precoce dans la perforation intestinale au cours de la fievre typhoide. *Arch. gen. Med.*, CLXXXVI, 14.

Concerning prompt surgical intervention for intestinal perforation in typhoid fever. *Ann. Surg.*, XXXIII, 544.

Concerning a definite regulatory mechanism of the vasomotor centre which controls blood pressure during cerebral compression. *Johns Hopkins Hosp. Bull.*, XII, 290.

Concerning the poisonous effect of pure sodium chloride solutions upon the nerve-muscle preparation. *Amer. Jour. Physiol.*, VI, 77.

Haller and his native town. *Amer. Med.*, II, 542.

Differenze dell' irritabilita dei nervi e dei muscoli. *R. C. Accad. Lincei*, X, 145.

*1902*

Saline irrigations and infusions. S. S. Cohen's System of physiologic therapeutics. P. Blakiston's Son and Co., IX, 279.

Physiologische und anatomische Beobachtungen über den Einfluss von Hirnkompression auf den intracraniellen Kreislauf und über einige hiermit verwandte Erscheinungen *Mitt. Grenzgeb. Med. Chir.*, IX, 773.

On the avoidance of shock in major amputations by cocainization of large nerve-trunks preliminary to their division. *Ann. Surg.*, XXXVI, 321.

Some experimental and clinical observations concerning states of increased intracranial tension. *Amer. Jour. Med. Sci.*, CXXIV, 375.

Exhibition of surgical cases. A ninth case of Gasserian ganglion extirpation. *Johns Hopkins Hosp. Bull.*, XIII, 248.

Treatment by the tourniquet to counteract the vasomotor spasm of Raynaud's disease. *Jour. Nerv. Ment. Dis.*, XXIX, 657.

*1903*

On routine determinations of arterial tension in operating room and clinic. *Boston Med. Surg. Jour.*, CXLVIII, 250.
The taste fibres and their independence of the N. trigeminus Deductions from thirteen cases of Gasserian ganglion extirpation. *Johns Hopkins Hosp. Bull.*, XIV, 71.
The surgical treatment of facial paralysis by nerve anastomosis. *Ann. Surg.*, XXXVII, 641.
The blood-pressure reaction of acute cerebral compression, illustrated by cases of intracranial hemorrhage. *Amer. Jour. Med. Sci.*, n.s, CXXV, 1017.
Exhibition of two cases of radicular paralysis of the brachial plexus. (With H. M. Thomas.) *Johns Hopkins Hosp. Bull.*, XIV, 315.

*1904*

Perineal zoster, with notes upon cutaneous segmentation post-axial to the lower limb. *Amer. Jour. Med. Sci.*, n.s., CXXVII, 375.
Pneumatic tourniquets: with especial reference to their use in craniotomies. *Med. News*, N. Y., LXXXIV, 577.
Intradural tumor of the cervical meninges. *Ann. Surg.*, XXXIX, 934.
The sensory distribution of the fifth cranial nerve. *Johns Hopkins Hosp. Bull.*, XV, 213.

*1905*

The special field of neurological surgery. *Cleveland Med. Jour*, IV, 1.
The surgical aspects of major neuralgia of the trigeminal nerve. *Jour. Amer. Med. Assn.*, XLIV: 773-778; 860-865; 920-929; 1002-1008; 1088-1093.
Diseases of the nervous system. Osler's Principles and Practice of Medicine, 6th edition, New York and London: Appleton and Co.
Introduction to: Comparative surgery; with illustrative cases. By C. M. Faris, H C. Thacher, J. F. Ortschild, and F. C. Beall. *Johns Hopkins Hosp. Bull.*, XVI, 179.
Concerning surgical intervention for the intracranial hemorrhages of the new-born. *Amer. Jour. Med. Sci.*, n. s. CXXX, 563.
The establishment of cerebral hernia as a decompressive measure for inaccessible brain tumors; with the description of intermuscular methods of masking the bone defect in temporal and occipital regions. *Surg. Gynec. Obstet.*, I, 297
Arteriovenous aneurysm of the occipital vessels. *N. Y. Med. Jour.*, LXXXII, 1305.

*1906*

On preservation of the nerve supply to the brow, in the operative approach to the Gasserian ganglion. *Ann. Surg.*, XLIII, 1.

Dr. Garth: The Kit-Kat Poet (1661-1718). *Johns Hopkins Hosp. Bull.*, XVII, 1.

Exhibition of surgical cases. (With Mr. Langnecker and Mr. Helmholz.) *Johns Hopkins Hosp. Bull*, XVII, 93.

Instruction in operative medicine. With the description of a course given in the Hunterian Laboratory of Experimental Medicine. *Johns Hopkins Hosp. Bull.*, XVII, 123.

The holders of The Gold-headed cane as book collectors. *Johns Hopkins Hosp. Bull.*, XVII, 166.

Cases of spontaneous intracranial hemorrhage associated with trigeminal nervi. *Jour. Amer. Med. Assn.*, XLVII, 178.

Elephantiasis nervorum of the scalp: A manifestation of von Recklinghausen's disease (With H F. Helmholz.) *Amer. Jour. Med. Sci.*, n. s., CXXXII, 355.

Sexual infantilism with optic atrophy in cases of tumor affecting the hypophysis cerebri. *Jour. Nerv. Ment. Dis.*, XXXIII, 704.

Introduction (With P. K. Gilman) to: Comparative surgery. Second series of reports. By F. W. Bancroft and E. S. Cross; G. R Henry; W D Gatch; J. G. Hopkins; A. R. Dochez; W. Von Gerber; and G. J. Heuer. *Johns Hopkins Hosp. Bull.*, XVII, 369.

*1907*

A discussion of some immediate and some remote consequences of cranial injuries. *N. Y Med. Jour.*, LXXXV: 97-107; 161-169; 208-216.

Exhibition of cases. Decompressive craniectomy for brain tumor; Gasserian ganglion operation for major neuralgia; exploratory craniotomy for Jacksonian epilepsy originating in the motor area of the lower extremity. *Johns Hopkins Hosp. Bull.*, XVIII, 142.

Remarks on some further modifications in the Gasserian ganglion operation for trigeminal neuralgia (sensory-root evulsion). *Trans. South Surg. Gynec. Assn.*, XIX, 480.

Remarks on the surgical treatment of facial paralysis and of trigeminal neuralgia. *Trans. Amer. Surg. Assn.*, XXV, 275.

Introduction (with J. F. Ortschild) to: Comparative surgery. Third series of reports. *Johns Hopkins Hosp. Bull.*, XVIII, 459.

*1908*

Presentation of cases. The subtemporal decompressive operation for the relief of pressure symptoms due to fracture of base of skull. *Johns Hopkins Hosp. Bull.*, XIX, 48.

Experimental and clinical notes on chronic valvular lesions in the dog and their possible relation to a future surgery of the cardiac valves. (With J. R. B. Branch.) *Jour. Med. Res.*, n. x., XII, 471.

Technical methods of performing certain cranial operations. *Interst. Med. Jour.*, XV, 171.

Technical methods of performing certain cranial operations. *Surg Gynec. Obstet.*, VI, 227.

Removal of a subcortical cystic tumor at a second-stage operation. (With H. M. Thomas.) *Jour. Amer. Med. Assn.*, L, 847.

Subtemporal decompressive operations for the intracranial complications associated with bursting fractures of the skull. *Ann. Surg.*, XLVII, 641.

Obstructive hydrocephalus following cerebrospinal meningitis, with intraventricular injection of antimeningitis serum (Flexner). (With F. J. Sladen.) *Jour. Exp. Med.*, X, 548.

Subtemporal decompression in a case of chronic nephritis with uremia. (With J. Bordley, Jr.) *Amer. Jour. Med. Sci.*, n. s., CXXXVI, 484.

Surgery of the head. In: Surgery, its principles and practice. W. W. Keen, Ed. W. B. Saunders Co., III, 17.

*1909*

Cases of brain tumor. *Johns Hopkins Hosp. Bull.*, XX, 22.

Some principles of cerebral surgery. *Jour. Amer. Med. Assn.*, LII, 184.

Observations on choked disc, with especial reference to decompressive cranial operations. (With J. Bordley, Jr.) *Jour. Amer. Med. Assn.*, LII, 353.

Observations in experimentally induced choked disc. (With J. Bordley, Jr.) *Johns Hopkins Hosp. Bull.*, XX, 95.

Is the pituitary gland essential to the maintenance of life? (With L. L. Reford.) *Johns Hopkins Hosp. Bull.*, XX, 105.

A note upon the faradic stimulation of the postcentral gyrus in conscious patients. *Brain*, XXXII, 44.

Discussion of: Prophylactic use of hexamethylenamin in cerebrospinal meningitis. By S. J. Crowe. *Johns Hopkins Hosp. Bull.*, XX, 154.

Report of the Committee on the Osler Testimonial. *Bull. Med. Chir. Fac. Maryland*, I, 238.

Some aspects of the pathological physiology of intracranial tumors. *Boston Med. Surg. Jour.*, CLXI, 71.

A method of combining exploration and decompression for cerebral tumors which prove to be inoperable. *Trans. Amer. Surg. Assn.*, 1919, XXVII, 565.

The hypophysis cerebri. *Jour. Amer. Med. Assn.*, LIII, 249.

Cases of cerebellar tumor, with the statistics of thirty operations. *Interst. Med. Jour.*, XVI, 607.

Alterations in the color fields in cases of brain tumor. (With J. Bordley, Jr.) *Arch. Ophthal.*, N. Y., XXXVIII, 451.

Effects of hypophyseal transplantation following total hypophysectomy in the canine. (With S. J. Crowe and J. Homans.) *Quart. Jour. Exp. Physiol.*, II, 389.

Partial hypophysectomy for acromegaly with remarks on the function of the hypophysis. *Ann. Surg.*, L, 1002.

*1910*

Recent observations on tumours of the brain and their surgical treatment. *Lancet*, I, 90.

The functions of the pituitary body. *Amer Jour. Med. Sci.*, n. x., CXXXIX, 473.

Experimental hypophysectomy. (With S. J. Crowe and J. Homans.) *Johns Hopkins Hosp. Bull.*, XXI, 127.

Strangulation of the nervi abducentes by lateral branches of the basilar artery in cases of brain tumour. *Brain*, XXX, 204.

Concerning the secretion of the infundibular lobe of the pituitary body and its presence in the cerebrospinal fluid. (With E. Goetsch.) *Amer. Jour. Physiol.*, XXVII, 60.

The special field of neurological surgery: five years later. *Johns Hopkins Hosp. Bull.*, XXI, 325.

Tumors of the brain and meninges. In: Osler's Modern Medicine. Lea and Febiger, VII, 418.

Hydrocephalus. In: Osler's Modern Medicine. Lea and Febiger, VII, 459.

Letter in: Western Reserve University. The Medical Department Endowment Fund. Cleveland, 4to, 18 pp.

*1911*

Brain tumors and their surgical treatment. *Can. Lancet*, XLIV, 507.

Carbohydrate tolerance and the posterior lobe of the hypophysis cerebri. (With E. Goetsch and C. Jacobson.) *Johns Hopkins Hosp. Bull.*, XXII, 165.

Distortions of the visual fields in cases of brain tumor. (First paper.) (With G. J. Heuer.) *Johns Hopkins Hosp. Bull.*, XXII, 190.

The control of bleeding in operations for brain tumors. With the description of silver "clips" for the occlusion of vessels inacessible to the ligature. *Ann. Surg.*, LIV, 1.

Distortions of the visual fields in cases of brain tumor. (Second paper.) (With G. J. Heuer.) *Jour. Amer. Med. Assn.*, LVII, 200.

Dyspituitarism. Harvey Lecture, 1910-1911, 31-45.

*1912*

Distortions of the visual fields in cases of brain tumor. (Third paper.) (With C. B. Walker.) *Arch. Ophthal.*, N. Y., XLI, 559.

*1913*

Further studies on the role of the hypophysis in the metabolism of carbohydrates. (With L. H. Weed and C. Jacobson.) *Johns Hopkins Hosp. Bull.*, XXIV, 40.

Robert Fletcher, 1823-1912. *Boston Med. Surg. Jour.*, CLXVIII, 330.

Concerning the symptomatic differentiation between disorders of the two lobes of the pituitary body: with notes on a syndrome accredited to hyperplasia of the anterior and secretory stasis or insufficiency of the posterior lobe. *Amer. Jour. Med. Sci.*, CXLV, 313.

Concerning diabetes insipidus and the polyurias of hypophysial origin. *Boston Med. Surg. Jour.*, CLXVIII, 901.

Hibernation and the pituitary body. (With E. Goetsch.) *Proc. Soc. Exp. Biol.*, II, 25.

The pars anterior and its relation to the reproductive glands. (With E. Goetsch.) *Proc. Soc. Exp. Biol.*, II, 26.

Operative experiences with lesions of the pituitary body. *Trans. Amer. Surg. Assn.*, XXXI, 467.

Realignments in greater medicine: their effect upon surgery and the influence of surgery upon them. *Brit. Med. Jour.*, II, 290.

The correlation of the organs of internal secretion and their disturbances. *Lancet*, II, 546.

The treatment of tumours of the brain and the indications for operation. *Lancet*, II, 552, 739.

Affections of the pituitary body. *Lancet*, II, 565.

Psychic disturbances associated with disorders of the ductless glands. *Amer. Jour. Insan.*, LXIX, 965.

Experiences with the meningeal fibro-endothelioma. *Jour. Nerv. Ment. Dis.*, XL, 41.

The perimetric deviations accompanying pituitary lesions (preliminary note). *Jour. Nerv. Ment. Dis.*, XL, 793.

*1914*

Studies on the cerebro-spinal fluid and its pathway. I. Introduction. *Jour. Med. Res.*, n. s., XXVI, 1.

Surgical experiences with pituitary disorders. *Jour. Amer. Med. Assn.*, LXIII, 1515.

The quatercentenary of Andreas Vesalius. 1514- *Boston Med. Surg. Jour.*, CLXXI, 995.

A centripetal versus a centrifugal hospital service. In: Peter Bent Brigham Hospital, Boston, Founder's Day, 1914. Boston: Privately printed.

*1915*

Studies on cerebro-spinal fluid. VIII. The effect of pituitary extract upon its secretion (choroidorrhoea). (With L. H. Weed.) *Amer. Jour. Physiol.*, XXXVI, 77.

Concerning the results of operations for brain tumor. *Jour. Amer. Med. Assn.*, LXIV, 189.

Portraits of Vesalius. *Med. Rec.*, N. Y., LXXXVII, 246.
Distortions of the visual fields in cases of brain tumour. (Fourth paper.) (With C. B. Walker.) *Brain*, XXXVII, 341.
From an ambulance surgeon's diary. *Harv. Alumni Bull.*, XVII, 608.
The Harvard Unit at the American Ambulance in Neuilly, Paris. *Boston Med. Surg. Jour.*, CLXXII, 801.
Hibernation and the pituitary body. (With E. Goetsch.) *Jour. Exp Med.*, XXII, 25.
Tumors of the brain and meninges. In: Osler's Modern Medicine. Lea and Febiger, 2nd ed.
Hydrocephalus. In: Osler's Modern Medicine. Lea and Febiger, 2nd ed.
The work of the American Ambulance Hospital in Paris. Privately printed.
Studies on the cerebro-spinal fluid and its pathway. No. IX. (With L. H. Weed.) *Johns Hopkins Hosp. Bull.*, XXVI, 367.
Report of the Surgeon-in-Chief. In: First annual report of the Peter Bent Brigham Hospital for the years 1913 and 1914. Cambridge, Mass.

*1916*

Hereditary anchylosis of the proximal phalangeal joints (symphalangism). *Genetics*, I, 90.
Headache. *Boston Med. Surg. Jour.*, CLXXIV, 325.
With the British Medical Corps in France. *Yale Rev.*, V, 523.
Concerning operations for the cranio-cerebral wounds of modern warfare. *Milit. Surg.*, XXXVIII, 601; XXXIX, 22.
Yale in medicine. In: The book of the Yale pageant. *Yale Univ. Press*, 150.
Studies of optic-nerve atrophy in association with chiasmal lesions. (With C. B. Walker.) *Arch. Ophthal.*, XLV, 407.
On convulsive spasm of the face produced by cerebello-pontine tumors. *Jour. Nerv. Ment. Dis.*, XL, 312.
Anosmia and sellar distension as misleading signs in the localization of a cerebral tumor. *Jour. Nerv. Ment. Dis.*, XL, 415.
Report of the Surgeon-in-Chief. In: Second annual report of the Peter Bent Brigham Hospital. Cambridge, Mass., 44.

*1917*

Experiences with acoustic tumors. *Johns Hopkins Hosp. Bull.*, XXVIII, 238.
The bombing of the Harvard Base Hospital. *Harv. Alumni Bull.*, XX, 80.
Fractures of the skull. Meninges, ependyma, and brain. Parts 1 and 2 of Chapter I (Surgery of the head). In: War surgery of the nervous system. War Department, Office of the Surgeon-General. Govt. Printing Office.

*1918*

Distortions of the visual fields in cases of brain tumor. (Fifth paper.) (With C. B. Walker.) *Arch. Ophthal.*, XLVII, 119.
Notes on penetrating wounds of the brain. *Brit. Med. Jour.*, I, 221.
A study of a series of wounds involving the brain and its enveloping structures. *Brit. Jour. Surg.*, V, 558.

*1919*

Considerations sur les plaies penetrantes du cerceau. *Arch Med. Pharm. milit.*, LXXI, 665.
Concerning "Harvard Units." (Letter to the Editor.) *Boston Med. Surg. Jour.*, CLXXX, 403.
Concerning the establishment of a National Institute of Neurology. *Amer. Jour. Insan.*, LXXVI, 113.
Neurological surgery and the war. *Boston Med. Surg. Jour.*, CLXXXI, 549.
Some neurological aspects of reconstruction. *Arch Neurol. Psychiat.*, II, 493.
Abstracts in: Manual of neuro-surgery. Govt. Printing Office, 119-149.

*1920*

List of publications from the Surgical Department of the Peter Bent Brigham Hospital and the Laboratory of Surgical Research, Harvard Medical School, 1912-1919. Boston: Privately printed.
Introduction to: The old humanities and the new science. By Sir William Osler, Houghton Mifflin Co., XXII, 64 pp.
The purpose and technical steps of a subtemporal decompression. In: Surgical Diagnosis and Treatment. By American Authors. A. J. Ochsner, Ed., Lea and Febiger, I, 407.
Brain tumor statistics. *Med. Rec.*, N. Y., XCVII, 417.
William Osler the man. *Ann. Med. Hist.*, II, 157.
Report of the Surgeon-in-Chief. In: Sixth annual report of the Peter Bent Brigham Hospital for the year 1919. Cambridge, Mass., 54.
Alterations of intracranial tension by salt solutions in the alimentary canal. (With F. E. B. Foley.) *Proc. Soc. Exp. Biol.*, XVII, 217.
Remarks on the acoustic neuromas and on ethmoidal operations for choked disc. *Trans. Amer. Laryng. Rhin. Otol. Soc.*, 129.
Two cases of splenectomy for splenic anemia. *Arch. Surg.*, I, 1.
Accessory sinus disease and choked disk. *Jour. Amer Med. Assn.*, LXXV, 236.
The major trigeminal neuralgias and their surgical treatment based on experiences with 332 Gasserian operations. First paper. *Amer. Jour. Med. Sci.*, CLX, 157.
The role of deep alcohol injections in the treatment of trigeminal neuralgia. *Jour. Amer. Med. Assn.*, LXXV, 441.

Biography of Sir William Osler. (Note) *Ann. Med. Hist.*, II, 303.

Funeral services of General William Crawford Gorgas and Lord Fisher *Boston Med. Surg. Jour.*, CLXXXIII, 315.

Discussion on perimetric methods. *Brit. Jour. Ophthal.*, IV, 467.

The special field of neurological surgery after another interval. *Arch. Neurol. Psychiat.*, IV, 603.

Cerebral surgery. *Trans. Amer. Neurol. Assn.*, 141.

Report of the Surgeon-in-Chief. In: Seventh annual report of the Peter Bent Brigham Hospital for the year 1920. Cambridge, Mass., 50.

Further concerning the acoustic neuromas. *Laryngoscope*, XXXI, 209.

Boston Society of Psychiatry and Neurology. *Arch. Neurol. Psychiat.*, V, 743.

Disorders of the pituitary gland. *Jour. Amer. Med. Assn.*, LXXVI, 1721.

Address at (Yale) Alumni meeting, New Haven, June 21, 1921. *Yale Alumni Weekly*, XXX, 1103.

The personality of a hospital. *Boston Med. Surg. Jour.*, CLXXXV, 529.

Remarks at conferring of honorary fellowships in the Royal College of Surgeons in Ireland. *Surg. Gynec. Obstet.*, XXXIII, 707.

Prefatory note to: Dedication exercises of the Oscar C. Tugo Circle, Boston. *Boston Med Surg Jour.*, CLXXXV, 739.

Distortions of the visual fields in cases of brain tumor. (Sixth paper). *Trans. Amer. Neurol. Assn.*, 374.

*1922*

Report of the Surgeon-in-Chief. In: Eighth annual report of the Peter Bent Brigham Hospital for the year 1921. Cambridge, Mass., 52.

A large epidermal cholesteatoma of the parieto-temporal region deforming the left hemisphere with cerebral symptoms. *Surg. Gynec. Obstet.*, XXXIV, 557.

Les syndromes hypophysaires au point de vue chirurgical. *Rev. neurol.*, XXXVIII, 779.

The cranial hyperostoses produced by meningeal endotheliomas. *Arch. Neurol. Psychiat.*, VIII, 139.

William Stewart Halsted, 1852-1922. *Science*, LVI, 461.

The meningiomas (dural endotheliomas); their source and favoured seats of origin. *Brain*, XLV, 282.

The physician and the surgeon. *Boston Med. Surg. Jour.*, CLXXXVII, 623.

Remarks on the bestowal of the Henry Jacob Bigelow Medal to Dr. W. W. Keen. *Boston Med. Surg. Jour.*, CLXXXVII, 650.

Laboratories: then and now. Toronto: Privately printed.

*1923*

Report of the Surgeon-in-Chief. In: Ninth annual report of the Peter Bent Brigham Hospital for the year 1922. Cambridge, Mass., 50.

Surgical end-results in general, with a case of cavernous haemangioma of the skull in particular. *Surg. Gynec. Obstet.*, XXXVI, 303.

Louisa Parsons, first superintendent of nurses in the University of Maryland Hospital. *Univ. Hosp. Nurses' Alumnae Bull.*, III, 3.

Contributions to the clinical study of intracranial aneurysms. *Guy's Hosp. Rept.*, LXXIII, 159.

Primary gliomas of the chiasm and optic nerves in their intracranial portion. (With P. Martin) *Arch. Ophthal.*, LII, 209.

The "Boston Tins." *Boston Med. Surg. Jour.*, CLXXXIX, 8.

Xanthochromia and increased protein in the spinal fluid above tumors of the cauda equina. (With J. B. Ayer) *Arch. Neurol. Psychiat.*, X, 381.

Neurological surgeons: with the report of one case. *Arch. Neurol. Psychiat.*, X, 381.

Notes on a series of intracranial tumors and conditions simulating them. *Arch. Neurol. Psychiat.*, X. 605.

*1924*

List of publications from the Surgical Department of the Peter Bent Brigham Hospital and the Laboratory of Surgical Research, Harvard Medical School, 1912-1923. Cambridge, Mass., *Univ. Press*, 23 pp.

The clinical teacher and the medical curriculum. *Jour. Amer. Med. Assn.*, LXXXII, 841.

George H. Simmons: Editor, publisher and writer. In: George H. Simmons. A testimonial. *Amer. Med. Assn.*, 24 pp.

Report of the Surgeon-in-Chief. In: Tenth annual report of the Peter Bent Brigham Hospital for the year 1923. Cambridge, Mass., 62.

The Western Reserve and its medical traditions. Cleveland: Privately printed.

Medulloblastoma cerebelli: A common type of mid-cerebellar glioma of childhood. (With P. Bailey) *Trans. Amer. Neurol. Assn.*, LXXXIX, 121.

Papillomas of the choroid plexus. (With L. E. Davis). *Trans. Amer. Neurol. Assn.*, 365-394.

*1925*

Microchemical color reactions as an aid to the identification and classification of brain tumors. (With P. Bailey.) *Proc. Nat. Acad. Sci.*, XI, 82.

Discussion of: Roentgenological aspects of brain tumors—meningiomas. By M. C. Sosman and T. J. Putnam. *Amer. Jour. Roentgenol.*, XIII, 1.

John Irvine Hunter, 1897-1924. *Boston Med. Surg. Jour.*, CXCII, 214.

Should Boston Have a Community Chest? (Editorial.) *Boston Traveler*, p. 16.

Robert Williamson Lovett, 1859-1924. *Boston Med. Surg. Jour.*, CXCII, 374.

Experiences with blood replacement during or after major intracranial operations. (With L. E. Davis.) *Surg. Gynec. Obstet.*, XL, 310

An eclipse observed over two centuries ago. *Harv. Alumni Bull.*, XXVII, 669.

Experimentum periculosum: judicium difficile. *Yale Alumni Weekly*, XXXIV, 801-803; 835-836.

Report of the Surgeon-in-Chief. In: Eleventh annual report of the Peter Bent Brigham Hospital for the year 1924. Boston, 69-117.

Prefatory note to: Chronic subdural hematoma. By T. J. Putnam. *Arch. Surg.*, II, 329.

Prefatory note to: A consideration of the hypophysial adenomata. By N. M. Dott and P. Bailey. *Brit. Jour. Surg.*, XIII, 314.

The third circulation and its channels. *Lancet*, CCIX, 851.

The pituitary gland as now known. *Lancet*, CCIX, 899.

Intracranial tumors and the surgeon. *Lancet*, CCIX, 956.

Ductless glands (discussion). *Trans. Congr. Amer. Phys. Surg.*, XIII, 61.

Foreword to: M. H. Spielmann's Iconography of Andreas Vesalius. London. John Bale, Sons and Danielsson, XXXXVII, 243 pp.

Introduction to· Facsimile edition of Cannano's Musculorum humani corporis picturata dissectio. Florence: R. Lier and Co., 47 pp.

*1926*

Report of the Surgeon-in-Chief. In: Twelfth annual report of the Peter Bent Brigham Hospital for the year 1925. Boston, 68.

Consecratio medici. *Jour. Amer. Med. Assn.*, LXXXVII, 539.

The value of books to the medical profession. *Med. Jour. Rec.*, CXXIV, 712.

*1927*

The doctor and his books. Cleveland, Ohio: Privately printed.

Care of head injuries and injuries to the spine and peripheral nerves in the forward hospitals. In: Medical Department of U. S. Army in the World War, Vol. XI, 755: Govt. Printing Office.

Diffuse tumors of the leptomeninges . two cases in which the process was revealed only by the microscope. (With C. L. Connor.) *Arch. Path. Lab. Med.*, III, 374.

The intracranial tumors of preadolescence. *Amer. Jour. Dis. Child.*, XXXIII, 551.

Report of the Surgeon-in-Chief. In: Thirteenth annual report of the Peter Bent Brigham Hospital for the year 1926. Cambridge, Mass., 65.

The transformation of a malignant paravertebral sympathicoblastoma into a benign ganglioneuroma. (With S. B. Wolbach.) *Amer. Jour. Path.*, XXX, 203.

James Ford Rhodes, 1848-1927. In: Later Years of the Saturday Club, 1870-1920. Houghton Mifflin Co.

Studies in acromegaly. IV. The basal metabolism. (With L. M. Davidoff.) *Arch. Intern. Med.*, XXXIX, 673.

Letter to *Time*. *Time*, May 23; IX, 2.

Studies in acromegaly. VI. The disturbances of carbohydrate metabolism. (With L. M. Davidoff.) *Arch. Intern. Med.*, XXXIX, 751.

Experiences with orbito-ethmoidal osteomata having intracranial complications. *Surg. Gynec. Obstet.*, XLIV, 721.

The meningiomas arising from the olfactory groove and their removal by the aid of electro-surgery. Glasgow: Jackson, Wylie and Co.

Acromegaly from a surgical standpoint. *Brit. Med. Jour.*, II, 1.

Emancipators. *Lancet*, II, 185.

Presentation of the Henry Jacob Bigelow Medal (to Dr. Rudolph Matas). *Boston Med. Surg. Jour.*, CXCVII, 701.

*1928*

Intracranial tumors. In: Osler's Modern Medicine. Lea and Febiger, 3rd ed., VI, 222.

Hydrocephalus. In: Osler's Modern Medicine. Lea and Febiger, 3rd ed., VI, 255.

Hemangiomas of cerebellum and retina (Lindau's disease). (With P. Bailey.) *Arch. Ophthal.*, LVII, 447.

Report of the Surgeon-in-Chief. In: Fourteenth annual report of the Peter Bent Brigham Hospital for the year 1927, Boston, 70.

The presentation of the Henry Jacob Bigelow Medal (to Dr. Chevalier Jackson). *New Engl. Jour. Med.*, CXCIX, 763.

Studies in acromegaly. VII. The microscopical structure of the adenomas in acromegalic dyspituitarism (fugitive acromegaly). (With P. Bailey.) *Amer. Jour. Path.*, IV, 545.

An account of the dedicatory ceremonies in connection with the Base Hospital No. 5 memorial. Privately printed (Merrymount Press), Boston.

Electro-surgery as an aid to the removal of intracranial tumors. *Surg. Gynec. Obstet.*, XLVII, 751.

Angioblastic meningiomas. (With P. Bailey and L. Eisenhardt.) *Arch. Path.*, VI, 953.

Meningiomas arising from the tuberculum sellae. (With L. Eisenhardt.) *Trans. Sect. Ophthal. Amer. Med. Assn.*, 322-408.

*1929*

Chronological list of publications from the Surgical Department of the Peter Bent Brigham Hospital and the Laboratory of Surgical Research, Harvard Medical School, 1912-1928. Boston: Privately printed.

Report of the Surgeon-in-Chief. In: Fifteenth annual report of the Peter Bent Brigham Hospital for the year 1928. Boston, 81.

The medical career. Hanover, N. H.: Dartmouth College.

Remarks at the Children's Hospital campaign dinner. News, March 15

Billroth letter. Orvoskepzes (special Billroth centennial number), XIX, 1.

Exercises in celebration of the bicentenary of the birth of John Hunter. *New Engl. Jour. Med*, CC, 810.

The chiasmal syndrome of primary optic atrophy and bitemporal field defects in adult patients with a normal sella turcica. *Trans. XIIIth Int. Ophthal. Congr.*, Amsterdam, 97-184.

The binding influence of a library on a subdividing profession. *Science*, LXX, 485.

*1930*

Experiences with the cerebellar medulloblastomas. *Acta path. microbiol. scand.*, VII, 1.

William Henry Welch. An anonymous contribution to: The eightieth birthday of William Henry Welch. New York: Privately printed, Milbank Memorial Fund.

Report of the Surgeon-in-Chief. In: Sixteenth annual report of the Peter Bent Brigham Hospital for the year 1929. Boston.

The separate growth-promoting and gonad-stimulating hormones of the anterior hypophysis: an historical review. (With H. M. Teel.) *Endokrinologie*, VI, 401.

The chiasmal syndrome. *Arch. Ophthal.*, III, 505-551; 704-735.

Studies in the physiological properties of the growth-promoting extracts of the anterior hypophysis. (With H. M. Teel). *Endocrinology*, XIV, 157.

An American tribute to Sir Anthony Bowlby. *St. Bart's Hosp. Jour.*, XXXVII, 199.

Neurohypophysial mechanisms from a clinical standpoint. *Lancet*, II, 119; 175.

Diagnosis of intracranial tumors by supravital technique. (With L. Eisenhardt). *Amer. Jour. Path*, VI, 541.

*1931*

Experiences with the cerebellar astrocytomas. *Surg. Gynec. Obstet.*, LII, 129.

Report of the Surgeon-in-Chief. In: Seventeenth annual report of the Peter Bent Brigham Hospital for the year 1930. Boston.

Eulogy of Major-General Clarence R. Edwards. Boston *Herald*, p. 3. (Feb. 16.)

A review of Homan's Textbook of Surgery. *New England Jour. Med.*, CCIV, 472.

Acknowledging reprints. A letter to the Editor. *Jour. Amer. Med. Assn.*, XCVI, 1168.

The posterior pituitary hormone and the parasympathetic nervous system. *Proc. Nat. Acad. Sci.*, 1931, XVII, 163; 239. 1932, XVIII, 500.

One hundred and fifty years. From tallow-dip to television. *New Engl. Jour. Med.*, CCIV, 1235.

George Strong Derby, 1875-1931. *New Engl. Jour. Med.*, CCV, 1262.

The surgical mortality percentages pertaining to a series of 2000 verified intracranial tumors. *Trans. Amer. Neurol. Assn.*, 456-463.

*1932*

The basophil adenomas of the pituitary body and their clinical manifestations (pituitary basophilism). *Johns Hopkins Hosp. Bull.*, L, 137.

Remarks at the presentation of the Henry Barton Jacobs Collection to the Welch Medical Library. *Johns Hopkins Hosp. Bull.*, L, 307.

Bemerkungen uber eine Serie von 2000 verifizierten Gehirntumoren mit der dazugehörigen chirurgischen Mortalitätsstatistik. *Chirurg*, IV, 254.

Peptic ulcers and the interbrain. *Surg. Gynec. Obstet.*, LV, 1.

Further concerning a parasympathetic center in the interbrain. (VII and VIII.) *Proc. Nat. Acad. Sci.*, XVIII, 500.

Further notes on pituitary basophilism. *Jour Amer. Med. Assn.*, XC, 281.

Report of the Surgeon-in-Chief. In: Eighteenth annual report of the Peter Bent Brigham Hospital for the year 1931. Boston, 74.

The specific dynamic action of protein in patients with pituitary disease. (With M. N. Fulton.) *Arch. Intern. Med.*, L, 649.

*1933*

Concerning a hypothalamic center for parasympathetic impulses. *Arch. Sc. Biol., Napoli*, XVIII, 107.

"Dyspituitarism": twenty years later. *Arch. Intern. Med.*, LI, 487.

Homo chirurgicus. *New Engl. Jour. Med.*, CCVIII, 922.

Medicine at the crossroads. *Jour. Amer. Med. Assn.*, C, 1567.

William Thomas Councilman, January 1, 1854-May 26, 1933. *Science*, LXXVII, 613.

In honor of Professor Elihu Thomson. *Science*, LXXVIII, 24.

Posterior pituitary activity from an anatomical standpoint. *Amer. Jour. Path.*, IX, 539.

*1934*

Hyperactivation of the neurohypophysis as the pathological basis of eclampsia and other hypertensive states. *Amer. Jour. Path.*, X, 145

Experimental pituitary basophilism. (With K. W. Thompson.) *Proc. Roy. Soc.*, 115 B: 88-100.

The Doctors Welch of Norfolk. *New Engl. Jour. Med.*, CCX, 1132.

The pioneer medical schools of Central New York. Syracuse, N. Y.: Privately printed.

From a surgeon's journal. *Atlantic Monthly*, 1934, CLIV, 385; 590; 696; 1935, CLV, 102.

*1935*

Psychiatrists, neurologists and the neurosurgeon. *Yale Jour. Biol. Med.*, VII, 191.

The humanizing of science. *Science*, LXXXI, 137.

William Beaumont's rendezvous with fame. *Yale Jour. Biol. Med.*, VIII, 113.

*1936*

Ivan Pavlow. *Soviet Russia Today*, April, p. 9.

Prefatory note to: The ultimate results of operations for intracranial tumours. By H. Cairns. *Yale Jour. Biol. Med.*, VIII, 421.

A bibliographical study of the Galvani and the Aldini writings on animal electricity. (With J. F. Fulton.) *Ann. Sci.*, I, 239.

Corrigenda and addenda to "The life of Sir William Osler." Oxford: University Press.

*1937*

Ercole Lelli and his écorché. *Yale Jour. Biol. Med.*, IX, 199.

Perry Williams Harvey, 1869-1932. *Yale University Libr. Gaz.*, II, 43.

Inhibition of action of pituitary hormones by animal sera. (With K. W. Thompson.) *Proc. Roy. Soc.*, 121 B: 501-517.

Remarks at Alumni luncheon, Yale University, 1937. *Yale Alumni Weekly*, XLVI, 23.

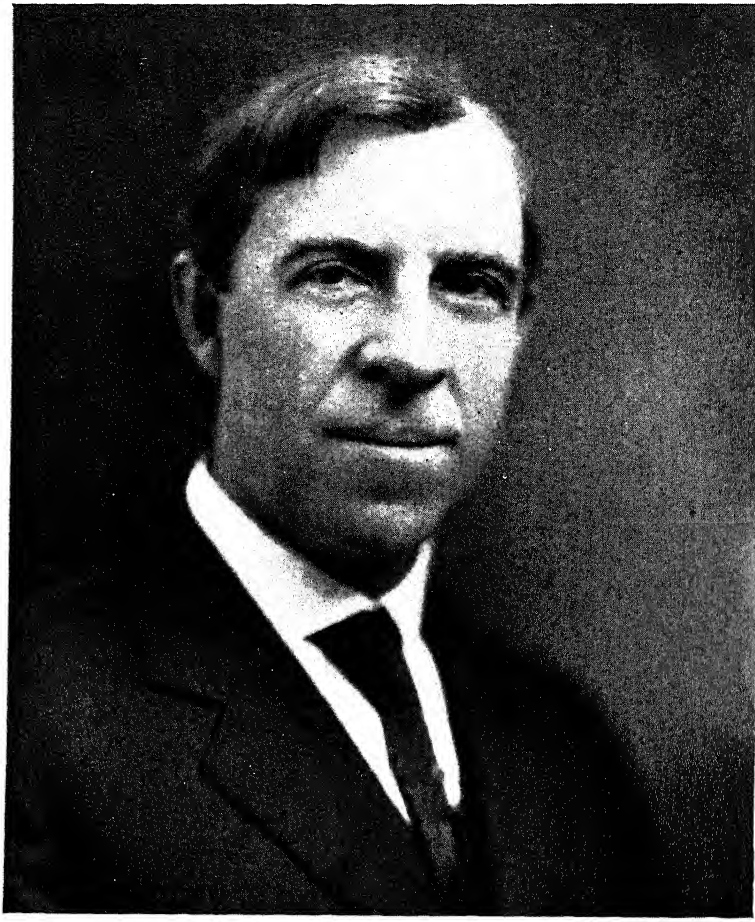
Toast given at luncheon, Association for Research in Nervous and Mental Disease, New York, Dec. 27, 1937. Reported in part: *New York Times*, Dec 28, 1937.

*1938*

Notes on the first reasonably successful removal of an intracranial tumor. (With L. Eisenhardt.) *Bull. Los Angeles Neurol. Soc.*, III, 95.

*1940*

The Medical Career. Little, Brown and Co. Collected papers and biographical sketch.



F. K. Richtmyer

NATIONAL ACADEMY OF SCIENCES

OF THE UNITED STATES OF AMERICA

BIOGRAPHICAL MEMOIRS

VOLUME XXII—FOURTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# FLOYD KARKER RICHTMYER

1881–1939

BY

HERBERT E. IVES

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1940

# FLOYD KARKER RICHTMYER

## 1881–1939

BY HERBERT E. IVES

The sudden death of Floyd Karker Richtmyer on November 7, 1939 ended a career unique in American physics for versatility and service. In addition to a full record as a teacher and investigator Richtmyer had served as president of three of the member societies of the American Institute of Physics, was editor of two of its journals, had been vice-president of Section B of the American Association for the Advancement of Science, and had taken a leading part in most of the important committees and councils in his field. To replace him, it has been necessary, as one faced with part of the responsibility remarked, to "enlist an army."

In reviewing a life of such far flung activities a strict chronological record would be apt to obscure the continuity of interest and effort which characterized Richtmyer's work in each of his fields. It is better, therefore, to group his work under several heads, and speak of each in turn, although no one line of work ever entirely occupied his undivided attention. The first group comprises his teaching and associated academic work. Next is his career as a scientific investigator. Then his work as editor and writer. Finally the work in which he was pre-eminent, as an organizer and committeeman in the several societies and groups for furthering physics in this country.

Richtmyer was born October 12, 1881, in the rural community of Cobleskill, New York. After attending local public schools he entered Cornell University, and graduated in 1904. He at once entered the teaching profession, which he never left, despite attractive offers from several large industrial laboratories. For two years he taught physics at Drexel Institute in Philadelphia. He then returned to Cornell University as instructor in physics. He there took his Ph.D. degree in 1910, was assistant professor 1911-18, and professor 1918 until his death. He became Dean of the Graduate School in 1931 and

held this post also until his death. In addition to teaching at Cornell he was visiting lecturer in physics at the University of California in the summer of 1923, at Stanford University in 1925 and 1931, and at Columbia University in 1929.

Properly falling under his teaching career was his membership in associations concerned with the problems of teaching. He was active for many years in the American Association of Physics Teachers, and after serving on various committees and editorial posts was president of this association 1937-38. In the Association of American Universities, he was at the time of his death the general secretary and chairman of two of its committees.

Richtmyer's characteristics as a teacher are well displayed in his well known book "Introduction to Modern Physics," first published in 1928. This, containing the subject matter of his special summer lectureships and his senior and graduate courses at Cornell, is a masterpiece of clear and logical presentation, noteworthy for its clarification for the beginner of the physical meaning of recent revolutionary physical theories, tracing their historical and experimental origin. The subject is not presented as a closed book, but the difficulties and many incomplete and unsatisfying features of physical theory are fully dwelt upon, in a manner to inspire thought and further study.

Richtmyer's work as an investigator falls under two distinct headings. As a graduate student at Cornell he was influenced by the late E. L. Nichols, to whose encouragement and guidance he expressed his indebtedness. It was therefore natural that his first research problems should be in the optical field to which Nichols devoted his life. We accordingly find Richtmyer publishing a series of papers on the then new field of photoelectricity. His work was chiefly on the application of photoelectric cells to photometric problems, and contributed part of the groundwork for their present extensive utilization in this kind of work. From this he was led naturally to other problems in photometry and illumination. A series of papers with E. C. Crittenden covers work done partly at the Bureau of Standards during a summer appointment in 1915, on heterochromatic photometry and the precision of photometric measurements.

During the period of his interest in this line of work Richtmyer served as chairman of the committee of the Illuminating Engineering Society on Education in Illumination for Engineers, and was a member of the council of the Society.

Following the war, during which he served as a civilian radio engineer in the Signal Corps (in which he later was commissioned a Major in the Reserve), Richtmyer sought a new field of research in which to initiate a long period program. For this he selected X-rays, and after a sabbatical year at the General Electric Company laboratory at Schenectady in 1919-20, proceeded to build up a laboratory at Cornell for precision work. Here for several years his attention was directed to problems of X-ray absorption, the principal result of which was to establish the law that absorption due to ionization in a given shell in an atom is proportional to the cube of the wavelength of the X-rays and to the fourth power of the wave number.

In 1927, after several months study in Siegbahn's laboratory in Uppsala, Richtmyer turned his attention to the problem of the faint X-ray lines known as "satellites." In picking an apparently subordinate phenomenon for study, Richtmyer was inspired by his belief that the answers to the major problems of physics have often come from running down obscure or discrepant effects. He often mentioned in this connection Planck's discovery of the quantum of energy as a result of trying to clear up the "shape" of the radiation-against wavelength curve of the black body. Closely along these lines Richtmyer carried out or supervised a number of investigations on the width and shapes of X-ray lines. In his vice-presidential address to Section B of the American Association the choice of the topic "The Romance of the Next Decimal Place" shows again Richtmyer's belief in the importance of clearing up minor phenomena or discrepancies. The study of satellites did in fact occupy the rest of Richtmyer's years of active research. He proposed a theory for the origin of these lines, ascribing them to jumps made simultaneously by two electrons in an ionized atom. He later recognized that while his proposed mechanism might account for some, most of the observed satellites are probably due to a mechanism proposed earlier by others, namely to a one

electron jump in a doubly ionized atom This all led, however, to the realization that the satellite problem was part of the broader one of the multiple inner ionization of atoms. His research program at Cornell, therefore, became a broad attack on this problem by studies of widths and shapes of X-ray lines and absorption limits, Auger transitions and their probabilities, and the relative intensities of satellite lines. With the increasing demands on his time for administrative work after 1930, Richtmyer's contribution to this program was increasingly one of inspection and supervision, but his mastery of technique and the guidance and experience he contributed played a dominant part in the productivity of those working in his laboratory.

Concurrently with his teaching and research work, Richtmyer had a distinguished career as an editor of scientific journals, and of a series of scientific text books—"The International Series in Physics," published by the McGraw-Hill Book Company. His active editorial work began with his assumption in 1922 of the business managership of the combined Journal of the Optical Society and the Review of Scientific Instruments. This combined journal was the result of a movement to establish a high grade scientific instrument journal in the United States which should be comparable in its influence with the German Zeitschrift fur Instrumentenkunde. In this movement the Association of Scientific Apparatus Makers of the United States of America took a leading part, and the project was partly underwritten by the National Research Council. It involved many considerations of policy and careful consideration of advertising and other sources of income. In the launching and guiding of this journal, Richtmyer, whose interest in instruments was always intense, applied himself unremittingly through the ten years of its existence, and in 1932, when the Review of Scientific Instruments became a separate journal under the Institute of Physics, he became the editor in chief, which post he retained until his death.

Beginning with the inception of the Optical Society of America, Richtmyer was an associate editor of its journal; was assistant editor during the period of its combination with the Review of Scientific Instruments, and from 1932 until his death

was the editor in chief. The great responsibilities of the editorship of these two journals did not, however, prevent him from accepting work as associate editor in other journals of the Institute of Physics. He was thus in continual active touch with practically the whole field of publication in American physics, and his experience, judgment, and constructive practical ideas were important and highly valued by all connected with these enterprises.

During the last ten years of his life Richtmyer's time and energy were largely devoted to administrative work in the several societies and important committees in the field of physics His career as society official indeed began before this, with his term as president of the Optical Society in 1920, and as president of Sigma Xi, 1924-26, but from the date mentioned he was occupied continuously in a range of executive and committee-work which was not only unique, but to anyone less energetic, enthusiastic and resourceful, would have become quite impracticable. He used to quote with approval the saying: "If you want to get a job done, ask a busy man to do it," and exemplified the saying in his own actions. He was repeatedly in demand for important posts, and his attitude was always to see if he could find a way to undertake the new job, and he usually did. There was no indication that his application to any one of these undertakings suffered by the number of commitments he made. On the contrary the experience and point of view of one was carried over to another, which probably simplified his own labors and certainly coordinated the work of the many organizations he served.

A listing of his offices can give an idea of their number but not of course of the constructive work he did in each. In the American Physical Society he served on the council from 1934 to 1935, was vice-president in 1935, and president in 1936. He was a member of the Executive Committee of the American Association of Physics Teachers 1931-39, vice-president 1935-36, and president 1937-38. When the American Institute of Physics was founded to coordinate the activities of the several physical societies, he became an active member, serving on various committees, and as a member of the Executive Committee

1934-39. Richtmyer devoted years of labor to the work of the National Research Council, was a member of the Executive Board 1924-27, 1930-35, a member of the Fellowship Board 1930-37, of the Division of Physical Sciences, 1923-35, vice chairman of that division 1927-29 and chairman 1930-35.

In addition to these positions in the physical groups, he was a life trustee of the National Geographic Society from 1939, an active member of the International Association of Ithaca, of which he was president for several years, and a member and chairman of the Board of Trustees of the Unitarian Church of Ithaca. He was a member of the Cosmos Club of Washington and of the Greek letter societies Gamma Alpha, Sigma Pi Sigma, Phi Delta Kappa, Phi Kappa Phi.

Numerous honors for his scientific work included the honorary Doctorate of Science of Lehigh University, the Levy Medal of the Franklin Institute in 1929, membership in the American Philosophical Society, 1935, and the American Academy of Arts and Sciences, 1935. He was elected to the National Academy of Sciences in 1932, and was elected to the Council of the Academy in 1938.

Richtmyer's personality was most attractive. He counted a host of friends among his scientific colleagues, and among the many younger men whom he wholeheartedly counseled, encouraged and aided. His appearance was always very much that of a country lad, a rather gangling figure, loosely dressed, with an honest and rugged face. As a conversationalist he was seriously attentive to the matter in hand, but was blessed with a strong sense of humor. He always appeared master of his problems, undiscouraged and untiring, but frank and modest.

Surviving him are his wife, Bernice Davis Richtmyer, and three children, Robert D., Sarah (Mrs. Mann), and Lawson D.

## BIBLIOGRAPHY OF F. K. RICHTMYER

### KEY TO ABBREVIATIONS

Amer. Phys Soc. Proc. = American Physical Society, Proceedings
Elec. World = Electrical World
Franklin Inst. Journ. = Franklin Institute, Journal.
Illum. Eng. = Illuminating Engineer.
Illum. Eng. Soc. Trans. = Illuminating Engineering Society, Transactions.
Opt. Soc. Amer. Journ. and Rev. Sci. Instr. = Optical Society of America, Journal and Review of Scientific Instruments.
Phil. Mag. = Philosophical Magazine.
Phys. Rev. = Physical Review.
Rev. Modern Phys. = Review of Modern Physics.
Rev. Sci. Instr. = Review of Scientific Instruments.
Sci. Mo. = Scientific Monthly.
Sib. Journ. Eng. = Sibley Journal of Engineering.
Tel. & Tel. Age. = Telegraph and Telephone Age.
U. S. Bur. Standards, Bull. = United States Bureau of Standards, Bulletin.

*1905*

Heat of vaporation of liquid air. (With R. C. Fenner.) *Phys. Rev.*, v. 20:, pp. 77-84.

*1909*

Dependence of photoelectric current on light intensity. *Phys. Rev.*, v. 29, pp. 71-8.

Photoelectric effect with the alkali metals. II. *Phys. Rev.*, v. 29, pp. 404-408.

*1910*

Photo-electricity of alkali metals. *Phys. Rev.*, v. 30, pp. 385-393; 394-396.

*1912*

Correcting the Hefner lamp for atmospheric moisture. *Illum. Eng.*, v. 5. pp. 397-398.

*1913*

Photoelectric cells in photometry. *Illum. Eng. Soc. Trans.*, v. 8, pp. 459-469.

*1914*

Effect of artificial illumination on vision. *Elec. World*, v. 64, pp. 519-521.

*1915*

Null method with photoelectric cells. *Phys. Rev.*, v. 6, pp. 66-68.

*1916*

Experiments on hetero-chromatic photometry. (With E. C. Crittenden.) *Illum. Eng Soc. Trans.*, v. 11, pp. 331-356; Disc., pp. 356-366.

*1918*

Industrial research laboratories. Introduction. *Sib. Journ. Eng.*, v. 32, pp. 80-84.

Comparison of flicker and equality-of-brightness photometer. (With E. C. Crittenden.) *U. S. Bur. Standards, Bull.*, 14, pp. 87-113.

*1919*

Magneto-resistance effects in films of bismuth. (With L. F. Curtiss.) *Phys. Rev.*, v. 14, pp. 536-537.

*1920*

The precision of photometric measurements; observation errors with different types of photometers. (With E. C. Crittenden.) *Opt. Soc. Amer. Journ.*, v. 4, pp. 371-387.

Magneto-resistance effects in bismuth films. (With L. F. Curtiss.) *Phys. Rev.*, v. 15, pp. 465-475.

The mass-absorption coefficient of water, aluminum, copper and molybdenum for x-rays of short wave-length. (With Kerr Grant.) *Phys. Rev.*, v. 15, p. 547.

*1921*

Mass-absorption coefficients as a function of wave length above and below the K x-ray limit of the absorber. *Phys. Rev.*, v. 17, pp. 264-265.

The evidence regarding the so-called "J" radiation in the characteristic x-ray spectra of the elements. *Phys. Rev.*, v. 17, pp. 433-434.

Absorption of x-rays. *Phys. Rev.*, v. 18, pp. 13-30.

Some problems of physiological optics. *Opt. Soc. Amer. Journ.*, v. 5, pp. 461-465.

*1922*

Cooperation between the makers and the users of apparatus in America. *Opt. Soc. Amer. Journ. and Rev. Sci. Instr.*, v. 6, pp. 483-488. Address before the Association of Scientific Apparatus Makers of America and the American Physical Society, Washington, April, 1922.

The size of the electron as determined by the absorption and scattering of x-rays. *Amer. Phys. Soc. Proc.; Phys. Rev.*, v. 20, pp. 87-88.

*1923*

Absorption of short x-rays by water and carbon. *Phys. Rev.*, v. 21, p. 478.

X-ray absorption coefficients of cobalt and nickel. (With F. W. Warburton.) *Phys. Rev.*, v. 21, p. 721.

Reflection of ultra-violet light by flowers. *Opt. Soc. Amer Journ*, *and Rev. Sci Instr.*, v. 7, pp. 151-168.

Absorption of x-rays by iron, cobalt, nickel, and copper. (With F. W. Warburton.) *Phys Rev*, v. 22, pp. 539-545.

*1924*

The relative number of K and L electrons expelled by x-rays. *Phys. Rev.*, v. 23, p. 292.

The structure of the K lines of molybdenum. (With R. C. Spencer.) *Phys. Rev.*, v. 23, pp. 550-551.

*1925*

The apparent shape of x-ray lines and absorption limits. *Phys. Rev.*, v. 26, pp. 724-735.

*1926*

Magnitude of the K-absorption discontinuity. Mass absorption coefficients for wave-lengths on both sides of the K limit. *Phys. Rev.*, v. 27, pp. 1-17.

"Seeing" with x-rays. *Sci Mo.*, v. 22, pp. 550-554. Radio lecture broadcast from station WCAP, Washington, D. C., under the auspices of the National Research Council.

*1927*

Absorption of x-rays in various elements. *Nature*, v. 120, pp. 915-916.

Comments on classical theory of x-ray absorption and refraction. *Phil. Mag.*, (7), v. 4, pp. 1296-1302.

Further experimental tests of theories of the absorption of x-rays. *Phys. Rev.*, v. 30, pp. 755-761.

The role of wave length in modern theories on phenomena of radiation. *Tel. and Tel. Age*, v. 45, pp. 225-226.

The variation of the absorption of x-rays with wave-length. *Science*, v. 65, p. 453. Abstract of paper presented at the annual meeting of the National Academy of Sciences, Washington, April 25-27, 1927.

Further test of the theories of absorption of x-rays. (With L. S. Taylor.) *Phys. Rev.*, v. 29, p. 606.

Relative probabilities of the photoelectric emission of electrons from silver and gold. (With L. S. Taylor.) *Phys. Rev.*, v. 29, pp. 353-354.

*1928*

Introduction to modern physics. New York, McGraw-Hill.

Multiple ionisation and absorption of x-rays. *Phil. Mag.*, v. 6, pp. 64-88.

*1929*

Secondary phenomena in x-ray spectra. *Franklin Inst., Journ.*, v. 208, pp. 325-362.

Satellites of x-ray lines $L\alpha$, $L\beta_1$, and $L\beta_2$. (With R. D. Richtmyer.) *Phys. Rev.*, v. 34, pp 574-581.

*1930*

Excitation potential of the $L\alpha$ satellites of gold (47). (With S. W. Barnes.) *Phys. Rev.*, v. 35, p. 661.

Satellites of $K\alpha$ for the elements nickel (28) to arsenic (33). (With E. Ramberg.) *Phys. Rev.*, v. 35, p. 661.

Direct-reading two-crystal spectrometer for x-rays. (With S. W. Barnes and E. Ramberg.) *Phys Rev*, v. 35, p. 1428.

Are the wave lengths of x-ray satellites affected by chemical combination? *Phys. Rev.*, v. 36, p. 457.

Hyperfine structure of x-ray lines. (With S. W. Barnes and K. V. Manning.) *Phys. Rev.*, v. 36, p. 1017.

Intensity of x-ray satellites. (With L. S. Taylor.) *Phys. Rev.*, v. 36, pp. 1044-1049.

*1931*

X-rays and their uses. *Sci. Mo*, v. 32, pp. 454-463. Science Service radio talks presented over the Columbia Broadcasting System.

A 600-kv. x-ray plant. (With H. A. Barton and M. T. Jones.) *Phys. Rev.*, v. 38, p. 176.

Forbidden x-ray lines in the L-series. (With S. Kaufman.) *Phys. Rev.*, v. 38, p. 1032.

The production of the molybdenum $L\alpha$ satellites by fluorescent absorption of silver $L\alpha$ radiation. (With F. R. Hirsh, Jr.) *Phys. Rev.*, v. 38, p. 1033.

*1932*

The romance of the next decimal place *Science*, v. 75, p. 1-5. Address of the retiring vice-president of Section B.—Physics, American Association for the Advancement of Science, New Orleans, Dec. 30, 1931.

*1933*

A history of the National Research Council, 1919-1933. II. Division of Physical Sciences. *Science*, v. 77, pp. 358-366.

New satellites of the x-ray line $L\beta_2$. (With S. Kaufman.) *Phys. Rev.*, v. 43, p. 562.

Determination of the shape, wave length and width of an x-ray absorption limit. (With S. W. Barnes.) *Phys. Rev*, v. 43, p. 754.

The change in relative intensity of the satellites of $L\alpha$ in the atomic-number range 47 to 52. (With F. R. Hirsh, Jr.) *Phys. Rev.*, v. 43, p. 754.

Device for reducing grain effects in microphotometer records. (With F. R. Hirsh, Jr.) *Rev. Sci. Instr.*, v. 4, pp. 353-354.

X-ray satellites of high atomic number elements. (With S. Kaufman.) *Phys. Rev*, v. 44, pp. 605-609.

Relative intensities of certain L-series x-ray satellites in cathode-ray and in fluorescence excitation. (With F. R. Hirsh, Jr.) *Phys. Rev.*, v. 44, pp. 955-960.

*1934*

Introduction to modern physics. 2d ed. New York, McGraw-Hill.

Direct-reading, two-crystal x-ray spectrometer. (With S. W. Barnes.) *Rev. Sci. Instr.*, v. 5, pp. 351-355.

Calculation of the x-ray energy level width of Au(79). (With E. Ramberg.) *Phys Rev*, v. 45, p. 644.

Auger effect for Au(79) and the origin of certain L-satellites in x-ray spectra. (With E. Ramberg.) *Phys. Rev.*, v. 45, p. 805.

Coster-Kronig theory of a new type of Auger effect. (With F. R. Hirsh, Jr.) *Phys. Rev*, v. 45, p. 805.

Natural widths of the K-series of W(74). (With S. W. Barnes.) *Phys Rev.*, v. 46, pp. 352-356.

The widths of the L-series lines and of the energy levels of Au(79). (With S. W. Barnes and E. Ramberg.) *Phys. Rev.*, v. 46, p. 843-860.

*1935*

Wave lengths of Kα x-ray satellite lines for elements S(16) to Ge(32). (With L. G. Parratt.) *Phys Rev.*, v. 49, p 644.

Widths of Kα x-ray satellite lines. (With L. G. Parratt.) *Phys. Rev.*, v. 49, p. 644.

*1936*

The absorption of ultra-short x-rays. *Phys. Rev.*, v. 51, p. 376.

L-satellites in the atomic number range $73<Z<79$. (With C. H Shaw and R. E. Shrader.) *Phys. Rev.*, v. 51, p. 380.

*1937*

The multiple ionization of inner electron shells of atoms. *Rev. Modern Phys.*, v. 9, pp. 391-402.

Radiation probabilities, Auger effect and energy level widths for Au(79). (With E. G. Ramberg.) *Phys. Rev.*, v. 51, pp. 913-925.

Satellite structure of Lα and $L\beta_2$ of Au(79). (With E. G. Ramberg.) *Phys. Rev.*, v. 51, pp. 925-929.

Determination of widths of energy states: Argon K absorption limit. (With L. G. Parratt.) *Phys. Rev.*, v. 52, pp. 678-679.

*1939*

Cornell University. Abstracts of theses, 1938. Cornell University Press, 473 pp.

F. K. Richtmyer also edited the International Series in Physics, published by McGraw-Hill.

Arthur E. Kennelly

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—FIFTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# ARTHUR EDWIN KENNELLY

1861–1939

BY

VANNEVAR BUSH

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1940

# ARTHUR EDWIN KENNELLY

## 1861–1939

BY VANNEVAR BUSH

To few, and only to the few, has been granted the inestimable privilege of active and close participation in almost the entire range of development of such an enormous and such a useful field as that of electrical engineering, from the pioneer days of the telegraph and submarine cable, through the earliest stages of practical application of the storage battery, the electric light, and the telephone, and on to the flowering of the art as represented by the present status of electric power generation, transmission, and utilization and of electrical communication. And to few only has there been granted the friendship, esteem, and professional respect of so many outstanding contemporaries in any art as are represented by such names as Rowland, Elihu Thomson, Edison, Steinmetz, Sprague, Houston, and Brush in the United States; Heaviside, Clark, Lord Kelvin, Fleeming-Jenkin, and Preece in England; Mascart, Blondel, and Ferrié in France; von Helmholtz in Germany, Marconi and Giorgi in Italy; Nagaoka in Japan; and many others throughout the world. But to Arthur Edwin Kennelly was granted both the privilege of such a participation in an art and such a friendship and esteem from the principal joint authors of its development. With his death on June 18, 1939, Harvard University and the Massachusetts Institute of Technology lost a deeply respected professor emeritus of electrical engineering, the profession lost one of its early pioneers and most striking figures, and the National Academy of Sciences lost a distinguished and valued member.

Dr. Kennelly was born at Colaba, Bombay, India, on December 17, 1861. His father, David Joseph Kennelly of Cork, Ireland, had gone to sea as a midshipman in 1845, served as a frigate commander in the Indian Mutiny of 1856-58, and was harbor master at Bombay from 1858-1868. His mother, Katherine Heycock Kennelly, born in Leeds, England, was a daughter of Edwin and Mary Heycock, who had settled in Bombay and built the first cotton mill in East India. Mrs. Kennelly died of

Indian fever in 1864[1] when Arthur was only three years old, and the child was sent to England because of the unfavorable climate of Bombay for rearing white children. He attended schools in France, Belgium, Scotland, and England, and particularly the University College School at Gower Street, London, where he received prizes in language and stenography. In later years his linguistic accomplishments were attested by his fluent command of French, German, and Italian. More significantly, he had inherited from his father an aptitude for arithmetic and geometry, although he modestly contended that his skill in mental arithmetic was only half that of his father.

Inspired at the age of twelve by a public lecture on "Submarine Telegraphy," given in Albert Hall, London, by Latimer Clark, the well-known telegraph engineer and inventor of the Clark potentiometer and the Clark cell, he decided to enter telegraph engineering, which, except for electroplating, represented the only industrial application of electricity at that time. This was before electrotechnical schools had been anywhere established. At fourteen he left school and entered the London office of the Society of Telegraph Engineers (later to become the Institution of Electrical Engineers) as office boy and assistant secretary. In this office he found the Ronalds' Electrical Library, and all his spare time was spent in studying electro-physics in the excellent collection of Ronalds' books, bequeathed to the Society by that pioneer telegrapher.

In 1876 at the age of fifteen he was appointed probationer telegraph clerk in the service of the Eastern Telegraph Company at its Porthcurno station near Land's End in Cornwall, England. This company owned and operated an extensive network of submarine telegraph cables connecting England with the continent of Europe, and through the Mediterranean Sea with Egypt, India, and the Far East. A year later he was sent to the Eastern Telegraph Company's Malta station as a junior operator, where he was allowed to assist in the periodical elec-

[1] Autobiographical notes sent to the National Academy of Sciences, Washington, D. C., give the date as 1863. In an *Abridged Record of Family Traits*, also in possession of the National Academy of Sciences, Kennelly gives the date as 1864.

trical tests of the cables landing at Malta. In 1878 he was transferred from the operating staff to the cable-ship staff as assistant electrician on board the *S. S. Chiltern*, remaining in this branch of service for eight years. In 1881 he was promoted to chief electrician on cable ships. His duties in this capacity were to test, repair, and lay submarine cables in various parts of the Eastern Telegraph Company's system, sharing the engineering responsibilities with the captains of the ships.

During these years Kennelly took part in numerous important cable repairs and the laying of cables from Gibraltar to Tangier, from Alexandria to Port Said, and in other places and served as chief electrician on a number of cable ships in all parts of the Eastern Telegraph Company's network between England and Bombay.

In 1887 after Kennelly had reached the position of senior chief electrician on the ship's staff of the Eastern Telegraph Company, he left that service to become assistant to Thomas A. Edison at his new laboratory in West Orange, New Jersey. He remained as Mr. Edison's principal electrical laboratory assistant for six years and during that time carried on a number of electrical researches. Between the years 1893 and 1901 he did a large amount of consulting electrical engineering work, first with the Edison General Electric Company and the General Electric Company of New York for a year and then with Edwin J. Houston in the firm of Houston and Kennelly in Philadelphia.

In 1902 the Mexican Government and the Safety Insulated Wire and Cable Company of New York placed Kennelly in charge of laying submarine telegraph cables from Vera Cruz to Frontera and Campeche. In the same year he was appointed professor of electrical engineering at Harvard, where he remained until his retirement as professor emeritus in 1930. From 1913-1925 he was also professor of electrical communication at the Massachusetts Institute of Technology; he directed its electrical engineering research for many years, was chairman of its faculty from 1917-1919, and became professor emeritus in 1930.

Besides his regular teaching at Harvard and Massachusetts Institute of Technology, Kennelly responded to invitations to lecture at many other universities in the United States, in

Canada, and in Europe. In 1921-22 he was sent by seven co-operating American universities (Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, Pennsylvania, and Yale), to lecture as their first exchange professor in engineering and applied sciences at six universities of France. And in 1931 he was appointed first visiting lecturer on the Iwadare Foundation at five universities in Japan. During the War he served as Civilian Liaison Officer in the Signal Corps of the United States Army overseas.

His publications were numerous and broad in scope. Of the twenty-eight books bearing his name on their title pages, he was sole author of ten. And in the course of his career he presented more than 350 papers before the leading scientific and technical societies here and abroad.[2]

Honorary degrees were conferred upon him by four universities: the University of Pittsburgh, 1895; Harvard University, 1906; the University of Toulouse, 1922; and the Technische Hochschule of Darmstadt, Germany, 1936. In 1939 he was made a member of the Royal Swedish Academy of Sciences. Among the many honors and awards received by him were the Institution Premium in 1887 and the Fahie Premium in 1889 from the Institution of Electrical Engineers, London; the Howard Potts gold medal from the Franklin Institute at Philadelphia for his invention of a hot wire anemometer, 1917; the Cross of a Chevalier de la Légion d'Honneur from France, 1922; the silver Volta medal, the Centenary medal of the Italian Government, received at the Como Convention, the annual gold medal of honor of the Institute of Radio Engineers, 1932; and the Edison Medal for 1933 from the American Institute of Electrical Engineers, awarded in January 1934. He was President for two terms of the American Institute of Electrical Engineers, 1898-1900; President of the American Metric Society, Washington, 1904; President of the Illuminating Engineering Society, New York, 1911; President of the Metric Association, 1915-1934; President of the Institute of Radio Engineers, New

[2] See List of Books and Papers by Dr. A. E. Kennelly, *Journal of the Electrotechnical Society of Waseda,* XIII (June-Aug. 1932), No. 7-8. See also bibliography below.

York, 1916; Honorary President of the Union Radio Scientifique Internationale, 1935; Vice President of the Edison Pioneers, 1938-1940; and in addition held memberships or honorary memberships in a score of other technical and scientific societies both here and abroad. He held appointments from time to time on some thirty scientific commissions and conferences, among which may be mentioned the following: Secretary and later Chairman of the Standards Committee of the American Institute of Electrical Engineers from the date of its inception to 1917; official delegate from the United States to the International Electrical Congress of Paris in 1900 and its Vice President; Chairman of the Committee on Nomenclature and Standards of the Illuminating Engineering Society, New York, from 1915-1921; technical adviser to the United States Delegation of the International Commission of Weights and Measures, Paris, 1921; delegate to the International meeting of the Conference of Large Electric Systems, Paris, 1921, and its Vice President; Research Associate of the Carnegie Institution of Washington, 1924-1936; Chairman of the Engineering Section of the National Academy of Sciences, 1932; and Vice Chairman of the Division of Foreign Relations of the National Research Council in 1933.

In July 1903 Kennelly married Dr. Julia Grice of Philadelphia, whose death preceded his by a few months. Their only surviving child, Reginald Grice Kennelly, was graduated *summa cum laude* from Harvard University in 1931 and received his doctor's degree from the same institution in 1935.

Expressive of the character of Kennelly and indicative of some of the achievements which he most valued in his career was the bookplate designed for him by Mr. W. A. Dwiggins, artist of Hingham and Boston, Massachusetts, in the winter of 1915-1916. It features a central ellipse enclosing a shield and scallop of the coat of arms of the Kennelly family. The legend, "Ora et Labora," is the family heraldic motto. Around the ellipse are twelve mathematical formulae relating to electrical circuits, for the formulation of which he was largely responsible. Another revealing item is his abridged family genealogy filed with the National Academy of Sciences, in which he particularly

notes that three generations of Kennellys have been total abstainers from both alcohol and tobacco.

To appreciate fully the position which Kennelly occupied in the development of the science and art of electrical engineering, one needs to have a clear idea of the roles of the originator and the interpreter. Kennelly was both; yet while his origination of theoretical matters was ample to assure him of a permanent position in history as a man of science, it was in the equally important aspect of interpretation that he was decidedly a unique figure. His carefully chosen nomenclature, his crystal clear exposition, his meticulous mathematical presentations, led thousands to employ powerful methods of analysis which would otherwise have remained abstruse and hence available only to a few. It is not too much to say that he changed the whole course of the methods of the electrical engineer by his leadership in this regard. As he interpreted mathematics for engineering use, he also originated new methods and new formulations. It is not necessary to inquire meticulously into all of these matters in regard to the ultimate credit for origination. The power of Kennelly to render clear and useful was his greatest contribution, and this often transcended the question of whether what he presented was new in an absolute sense, or new in the sometimes equally important sense of being unknown and inaccessible to those who could best employ it in bringing to the public the benefit of the applications of science in an economical manner.

This comment applies especially to Kennelly's extensive contributions in the field of circuit theory. The direct-current circuits on which the early advances in electrical engineering were based, required for their analysis only simple algebra. Hence, as soon as instruments for reasonably precise measurement were available, the use of such circuits proceeded without impediment from lack of analysis. Alternating-current circuits were of a very different nature, and the transient phenomena of circuits of more difficult nature still. In a field of application where the flow of energy can ordinarily be neither seen, heard, nor felt, procedure by rule of thumb, design on the basis of qualitative experience, could not have gone far. The revolution in our daily lives, due to the widespread use of alternating currents

in power applications and communication, has been possible primarily because electrical engineers can precisely analyze in advance the performance of the complex electrical networks involved. This has been accomplished largely because those engineers use in their daily work mathematical methods of analysis in exceedingly convenient form and of extraordinary power. Kennelly was distinctly in the forefront of the advance which made this possible.

The mathematicians had long dealt with so-called imaginary and complex variables, and had met them in connection with the solution of some of the differential equations of physics. Heaviside had approached the problems of electrical circuits with no mathematical inhibitions whatever, and, by unorthodox methods sometimes entirely divorced from all questions of rigor, had produced the extraordinary results for which we are so greatly indebted to him. There was needed, however, some individual who could regularize, interpret, simplify, and extend the mathematical approach in order to create a keen working tool. This was Kennelly's great work.

Fortunately we have Kennelly's own recital of the various steps in this process of development of electric circuit theory, and his own meticulous statements as to the specific accomplishments which he claimed as the result of his own origination, preserved in his Academy autobiography. The most important parts of this document have been quoted by Professor Dawes in a biography of Kennelly published in *Science* shortly after his death, and there is hence no need for further quotation here. The record seems rather to need expansion in order that scientists in other fields may more fully appreciate the significance of the work which Kennelly performed in the specialized fields in which he was long engaged.

As early as 1887 he published his method of localizing electrically faults in submarine cables by varying the testing current strength.[3] This method he had invented by observing the apparent resistance of a copper exposure at a break and relating

[3] A. E. Kennelly, "The Resistance of Faults in Submarine Cables," *Journal of the Society of Telegraph Engineers and Electricians*, XVI (March 17, 1887), pp. 219-249.

it to the square root of the testing current through the exposure. It should be noted that there were no ammeters in existence at the time, and the establishment of a relationship of this sort called for great ingenuity and resourcefulness in measurement. Kennelly's paper on the subject received the "Institution Premium" of the Society of Telegraph Engineers, London, and the method set forth continues to be a recognized one for fault localization.

Neat generalizations and apt formulations soon began to appear. The idea of the "center of gravity" of cable faults [4] led to the application of the same general thought in regard to the complex loads of polyphase systems.[5] The fact that certain circuits are equivalent in external reaction, so that one may be freely substituted for its equivalent in either analysis or practice, is a far-reaching thought. The most striking substitutions involve "delta" and "star" arrangements, each of three branches and arranged respectively in triangular or radial conformation. Kennelly showed the complete conditions for equivalence in very convenient form in 1899.[6]

His most notable accomplishment along these lines had to do with Ohm's law. This was the law of proportionality of current and potential difference which was basic to all work with steadily flowing currents. When alternating-current circuits appeared, with sinusoidally varying parameters, no such convenient tool was at hand. The basis of analysis resided, it is true, in the mathematical theory of vibrations, but the application to electrical circuits was far from obvious or direct. Kennelly's paper of 1893, entitled "Impedance," [7] crystallized the matter in such form that engineers soon began to use plane vectors and complex numbers with freedom and precision. Complex algebra

[4] A. E. Kennelly, "On the Analogy between the Composition of Derivations in a Telegraph Circuit into a Resultant Fault and the Composition of Gravitation on the Particles of a Rigid Body into a Center of Gravity," *Electrical Review*, New York, XI (November 5, 1887), pp. 2-3.

[5] A. E. Kennelly, "On the Determination of Current Strength in Three-Pointed Star Resistance Systems," *The Electric World and Engr.*, XXXIV (August 19, 1899), pp. 268-270.

[6] A. E. Kennelly, "The Equivalence of Triangles and Three-Pointed Stars in Conducting Networks," *ibid.* (September 16, 1899), pp. 413-414.

[7] A. E. Kennelly, "Impedance," *Transactions of the American Institute of Electrical Engineers,* X (April 18, 1893), pp. 175-216.

rendered the alternating-current circuit almost as readily amenable to treatment as had been the direct-current circuits which preceded.

After this advance the treatment of circuits of discrete parameters in the steady state was well ordered. A similar clarification soon followed in regard to those circuits, such as long transmission or communication lines, where the parameters are distributed. Again the fundamental differential equations followed immediately from those of Maxwell and had long been known. Heaviside had given in 1891 the solutions in terms of hyperbolic functions expressed in scalon form. The subject was much advanced, however, when Kennelly in 1894 [8] gave a clear and explicit solution in terms of complex hyperbolic functions, and still further when he introduced a notation for polar complex quantities and published sets of tables and charts of the trigonometrical functions of complex angles.

The same clarification also appeared in connection with circuits in free oscillations. Here there was a large mathematical background indeed in regard to the behavior of free mechanical systems, which applied as well to the equivalent electrical networks. The parallelism between this behavior and that of the steady state became fully clear to many only when Kennelly published in 1915 [9] a treatment in which notation was carefully carried over from one to the other.

It is not necessary to review in detail the work on dissymmetrical networks,[10] nor the large amount of accomplishment in regard to artificial lines.[11] In some of this, largely as a by-product, he extended the knowledge of certain types of con-

[8] A. E. Kennelly, "On the Fall of Pressure in Long Leads Traversed by Alternating Currents," *The Electrician*, XXXII (January 5, 1894), pp. 239-240.

[9] A. E. Kennelly, "The Impedances, Angular Velocities and Frequencies of Oscillating-Current Circuits," *Proceedings of the Institute of Radio Engineers*, November 1915.

[10] A. E. Kennelly, "Dissymmetrical Electrical Conducting Networks," *Journal of the American Institute of Electrical Engineers* (February 1923), pp 112-122.

[11] A. E. Kennelly, "Artificial Lines for Continuous Currents in the Steady State," *Proceedings of the American Academy of Arts & Sciences*, XLIV (November 1908), pp. 97-130; "The Equivalent Circuits of Composite Lines in the Steady State," *ibid.*, XLV (November 1909), pp. 31-75; *Electric Lines and Nets*, New York: McGraw-Hill Book Company, 1928.

tinued fractions.[12] He also investigated at length the phenomenon of "skin-effect" by which the current crowds toward the periphery of alternating-current conductors, and followed this matter both theoretically and experimentally.[13] There was extensive work on the heating of wires carrying current,[14] and upon the performance of the telephone receiver.[15]

Lest it be thought, however, that all of Kennelly's work had to do with precise analysis, mention should be made of his accomplishments of a somewhat different nature.

Most notable of these was the brilliant inspiration by which he dissipated the mystery surrounding the progress of radio waves over the surface of the earth. In 1901 Marconi announced the reception in Nova Scotia of radio signals from a

---

[12] A. E. Kennelly, "The Expression of Constant and Alternating Continued Fractions in Hyperbolic Functions," *Harvard Annals of Mathematics*, IX, second series (January 1908), pp. 85-96.

[13] A. E. Kennelly, "Impedance," *Transactions of the American Institute of Elec. Engrs.*, X (April 18, 1893), pp. 175-216; A. E. Kennelly, F. A. Laws, and P. H. Pierce, "Experimental Researches on Skin Effect in Conductors," *ibid.*, XXXIV (September 1915), pp. 1953-2021; A. E. Kennelly, F. H. Achard, and A. S. Dana, "Experimental Researches on Skin Effect in Steel Rails," *Journal of the Franklin Institute*, CLXXXII (1916), pp. 135-139; A. E. Kennelly and H. A. Affel, "Skin Effect Resistance Measurements of Conductors at Radio Frequencies up to 100,000 Cycles per Second," *Proceedings of the Institute of Radio Engineers* (December 1916), pp. 523-574; A. E. Kennelly, "Notes from the Research Division Electrical Engineering Department, Mass. Inst. Tech.," *Journal of the Franklin Institute*, CLXXXIII (1917), pp. 509-511.

[14] A. E. Kennelly, "Heating Conductors by Electric Currents," Convention of the Assoc. Edison Illum. Cos., Niagara Falls, New York (August 13, 1889), pp. 11-32; A. E. Kennelly, C. A. Wright and J. S. Van Bylevelt, "The Convection of Heat from Small Copper Wires," *Transactions of the American Institute of Electrical Engineers*, XXVIII (June 1909), pp. 363-393; A. E. Kennelly and H. S. Sanborn, "The Influence of Atmospheric Pressure upon the Forced Thermal Convection from Small Electrically Heated Platinum Wires," *Proceedings of the American Phil. Society*, LIII (April 1914), pp. 55-57; A. E. Kennelly and E. R. Shepard, "The Heating of Copper Wires by Electric Currents," *Proceedings of the American Institute of Electrical Engineers*, XXVI (June 1907), pp. 969-995; A. E. Kennelly, F. D. Everett and A. A. Prior, "Thermal Insulation Tests of Electrical Ovens," *Electric World*, LXV (March 27, 1915), p. 779.

[15] A. E. Kennelly, "A Contribution to the Theory of Telephony," *Electrical World*, XXIII (February 27, 1894), p. 208; A. E. Kennelly and W. L. Upson, "The Humming Telephone," *Proceedings of the American Philosophical Society* (July 1908), Vol. 47, pp. 329-365; A. E. Kennelly and G. W. Pierce, "The Impedance of Telephone Receivers as Affected by the Motion of Their Diaphragms," *Electrical World*, LX (September 14, 1912), pp. 560-565.

station in England. The received energy was far greater than could have been expected from any simple three-dimensional wave expansion. Moreover, if one assumed free propagation in the entire region above the earth and complete shielding by the conducting earth itself, which would have been quite reasonable at the time, there was no reason for expecting any signal at all. Yet Marconi, perhaps because he was fortunate in not possessing the incomplete current knowledge of the phenomena involved, tried the experiment, and the signals were received. Kennelly provided the explanation,[16] by reason of the reflection of the waves from an upper stratum of ionized air, basing his explanation on some of the properties of rarefied gases which had just been announced by J. J. Thomson. The ionized reflecting layer is usually called the Kennelly-Heaviside layer in view of the fact that Heaviside published essentially the same explanation later in the same year in the Encyclopaedia Britannica. Since that time there has been much study of the phenomena, and the layer is found to be multiple with extraordinary variations in position and composition.

Kennelly made important contributions to illumination[17] at a time when the art was greatly in need of better methods of measurement. In the course of many years his influence was felt in nearly every aspect of electrical engineering. Entirely apart from his strictly scientific and technical achievements, his influence on standardization and international interchange was profound.

[16] A. E. Kennelly, "On the Elevation of the Electrically-Conducting Strata of the Earth's Atmosphere," *Elec. World and Engr.*, XXXIX (March 15, 1902), p. 473.

[17] E. J. Houston and A. E. Kennelly, "An Instrument for Measuring the Mean Spherical Candlepower of Arc Lamps," *The Electric World*, XXVII (May 9, 1896), p. 509; A. E. Kennelly and S. E. Whiting, "The Frequencies of Flicker at which Variations in Illumination Vanish," *ibid.*, XLIX (June 1907), pp. 1208-1209; A. E. Kennelly, G. R. Carter, S. C. Li, and E. A. Healey, "Flicker on Fixed and Rotating Targets," *Proceedings of the Illum. Engineering Society* (February 1911), p. 120; A. E. Kennelly, "A New Graphic Method for Determining the Mean Spherical Intensity of a Lamp by the Length of a Straight Line when the Curve of Mean Meridional Intensity is Given," *Electrical World, LI* (March 28, 1908), pp. 645-649: "A Rectilinear Graphical Construction of the Spherical Reduction Factor of a Lamp," *Proceedings of the Illum. Engineering Society* (February 1908).

All who were his students remember him as a remarkable teacher, whose clarity and precision of expression made smooth the path of those struggling with the often abstruse intricacies of electrical phenomena. Moreover, there was always a bit of humor to relieve the tedium.

He was at his best at a scientific meeting, where his geniality and ready wit enlivened many a discussion. In international gatherings in particular his precision of language, his unfailing courtesy, and his wide acquaintance aided greatly in bringing about understanding and good will.

After his formal retirement from active teaching in 1930 he remained a valued member of the academic community in Cambridge. His eyesight failed rapidly, but he continued actively, and worked at his office every day even when nearly totally blind. Under these conditions he wrote several of his last papers, aimed at simplifying and coordinating the systems of units used by electrical engineers.

Arthur Edwin Kennelly died on June eighteenth, 1939, honored by scientific men everywhere, and leaving as a monument to his work some three hundred and fifty publications of constant contribution to the art and science of electrical engineering.

## BIBLIOGRAPHY OF ARTHUR EDWIN KENNELLY

### (A) List of Books Published by Dr. A. E. Kennelly

(1) Theoretical Elements of Electro-Dynamic Machinery. 87 pp. D. Van Nostrand Co., 1893.

(2) Wireless Telegraphy. 211 pp. Moffat, Yard & Co., N. Y., 1906. Later edition, Wireless Telegraphy and Wireless Telephony. 230 pp. Moffat, Yard & Co., 1909.

(3) The Application of Hyperbolic Functions to Electrical Engineering Problems. 273 pp. University of London Press, 1912. 1919, 1925.

(4) Tables of Complex Hyperbolic and Circular Functions. 212 pp. Harvard University Press, 1914.

(5) Chart Atlas of Complex Hyperbolic and Circular Functions. Harvard University Press, 1914. 27 charts.

(6) Artificial Electric Lines, Their Theory, Mode of Construction, and Uses. 348 pp. McGraw-Hill Book Co., N. Y., 1917.

(7) Les Applications élémentaires des fonctions hyperboliques à la science de l'ingénieur électricien. 153 pp. Gauthier-Villars. Paris, 1922.

(8) Electrical Vibration Instruments. 450 pp., 213 ills. The Macmillan Co., N. Y., 1923.

(9) Vestiges of Premetric Weights and Measures Persisting in Metric System Europe, 1926-27. 189 pp. The Macmillan Co., N. Y. 1928.

(10) Electric Lines and Nets. 426 pp., 222 ills. A revision and enlargement of No. 6. McGraw-Hill Book Co., 1928.

### (B) By A. E. Kennelly and H. D. Wilkinson

(1) Practical Notes for Electrical Students. 308 pp. The Electrician Printing Co., 1890.

### (C) By E. J. Houston and A. E. Kennelly

(1) Electro-Dynamic Machinery for Continuous Currents. 341 pp. W. J. Johnston Co., 1896.

(2) Electric Heating. 290 pp.

(3) Electric Incandescent Lighting. 449 pp.

(4) Magnetism. 294 pp.

(5) Electric Arc Lighting. 383 pp.

(6) The Electric Telephone. 453 pp.

(7) Electric Telegraphy. 448 pp.

(8) Alternating Electric Currents. 225 pp.

(9) Electricity in Electro-Therapeutics. 402 pp.

(10) Electric Motors. 377 pp.

(11) Electric Street Railways. 365 pp.

Electrotechnical Series, 1897. McGraw-Hill Book Co. (Elementary text books)

Electric Engineering Leaflets

(12) Elementary. 299 pp.
(13) Intermediate. 299 pp. } *Electrical Engineer*, N. Y., 1897
(14) Advanced. 296 pp.

(15) Recent Types of Dynamo-Electric Machinery. 612 pp. American Technical Book Co.

(16) Algebra Made Easy. 125 pp. American Technical Book Co., 1897 (elementary)

(17) The Interpretation of Mathematical Formulae. 225 pp. American Technical Book Co., 1898 (elementary)

(18) Electricity made easy by simple language and copious illustration. 348 pp. American Technical Book Co., 1898.

**(D) Approximate List of Papers Published by Dr. A. E. Kennelly***

*1881*

(1) In a Cyclone. Correspondence Column, *Electrician*, Vol. 7, pp. 166-167.

*1883*

(2) Improvements in Fault-Localisation Test by Fall of Potential. Correspondence Column, *Electrician*, Vol. 11, pp. 85-88.

*1885*

(3) On a Method of Localising a Partial Earth in a Cable When a Return Wire is Not Available. (With J. Anderson.) *Electrician*, Vol. 15, pp. 177-181.

*1886*

(4) Formulae for Maintaining the Constancy of Testing Currents through a Fault in Blavier Localisation Measurements. Correspondence Column, *Electrician*, Vol. 16, pp. 267-269.

*1887*

(5) The Resistance of Faults in Submarine Cables. *Jour. Soc. Tel. Eng. and Electr.*, Vol. 16, pp. 219-249. Paper received "Institution" Premium of the Society, Vol. 16, p. 641.

(6) On the Localisation of a Complete Fracture in a Submarine Cable by Bridge Measurement to Instrument Zero. *Electrician*, Vol. 19, pp. 480-482 and 489-499.

(7) On the Superiority of the "Earth-Overlap" Method in Localising Small Faults in Submarine Cables when No Loop is Available, as Evidenced by Recent Practical Results with a Fault of 40,000 Ohms in a Cable of 1140 Ohms Conductor Resistance. *Jour. Soc. Elec. Eng. and Electr.*, Vol. 16, pp. 581-585.

* A number of scattered titles are missing from this list, probably more than fifty. About five hundred unsigned editorial articles were also printed in the *Electrical World* between 1895 and 1921. Two editorials a week were sent in from 1895-1915; after that, less often.

(8) On the Analogy between the Composition of Derivations in a Telegraph Circuit Into a Resultant Fault and the Composition of Gravitation on the Particles of a Rigid Body into a Center of Gravity. Dated London, Oct. 1887. *Elec. Rev.*, Vol. 11, pp. 2-3.

(9) Letters from Learners. *Electrician*, Vol. 20, pp. 30, 52, 75, 128, 153, 179.

*1888*

(10) The Edison Ground Detector for Electric Light Circuits. *Elec. World*, Vol. 12, p. 6.

(11) Tests of Primary Batteries. *Elec. World*, Vol. 12, pp. 107-108.

(12) Notes on the Reduction of Ballistic Observations to Absolute Measure. *Electrician*, Vol. 21, pp. 694-696.

(13) On the Voltametric Measurement of Alternating Currents. *Electrician*, Vol. 21, pp. 724-725.

*1889*

(14) On Certain Phenomena Connected with Imperfect Earth in Telegraph Circuits. *Jour. Inst. Elec. Eng. and Elect.*, Vol. 18, pp. 129-146. Paper received "Fahie" Premium, Vol. 18, p. 826.

(15) Iron Sheathing and Speed in Submarine Cables. *Elec. World*, Vol. 13, p. 158.

(16) Correction of Error in the Scale of Thompson Galvanometers Due to the Doubling of Deflection Angles by the Reflected Beam of Light. *Elec. World*, Vol. 13, p. 216.

(17) The Law of Probability of Error as Applied to the Observed Resistance of the Human Body. *Elec. World*, Vol. 14, pp. 73-74.

(18) Heating Conductors by Electric Currents. Convention of the Assoc. Edison Illum. Cos., Niagara Falls, N. Y., pp. 11-32. Abstracted also in *Electrician*, Vol. 24, pp. 142-3, 169-72, 194-6; also in *Elec. World*, Vol. 14, pp. 135, 336, 355, 372, and 386.

(19) Convenient Null Method of Measuring Mutual Inductance. *Elec. World*, Vol. 14, p. 230.

*1890*

(20) Alternating versus Continuous Currents in Relation to the Human Body. *Electrician*, Vol. 25, p. 17.

(21) Permeability of Iron at Right Angles to the Direction of Magnetisation. *Electrician*, Vol. 25, pp. 111-114, and 141-144. Mentioned by Ewing in same volume, p. 515.

(22) On the New Standard Edison Electrolytic Meter. *Elec. World*, Vol. 16, p. 230.

(23) On the Best Dimensions for Standard Optical Ammeters and Voltmeters. *Electrician*, Vol. 25, pp. 701-703.

(24) An Account of an Experiment Made to Determine Whether Gravitation Force Varies with Temperature. *Proc. Astr. Soc. Pacific*, pp. 23-26.

(25) Electricity in the Household. A chapter in "Electricity in Daily Life." Charles Scribner's Sons, N. Y., 1890 pp. 239-260. First appeared as an article in *Scribner's Magazine*, 1890.

(26) Inductance and Its Proposed Unit the Henry. *Trans. Amer. Inst. Elec. Engs.*, Vol. 8, pp. 2-18. Also *Electrician*, Vol. 26, pp. 267, 305, 385.

*1891*

(27) Note on the Relative Degree of Disturbance Caused by Electrostatic and Electromagnetic Induction between Telephone Circuits. *Electrician*, Vol. 26, p. 763. Also *Elec. World*, Vol. 17, p. 277.

(28) Experiments on the Ratio of Electrostatic to Electromagnetic Inductive Disturbance between Neighboring Telephone Circuits. *Electrician*, Vol. 27, pp. 35-36.

(29) Magnetic Reluctance. *Trans. Am. Inst. Elec. Engs.*, Vol. 8, pp. 485-517.

(30) Report of Committee on Units and Standards. List of New Units Practically Needed for Convenience in Dealing with Magnetic Circuits. *Trans. Am. Inst. Elec. Engs.*, Vol. 8, pp. 533-534.

*1892*

(31) Physiological Observations at the McIlvaine Electrocution. *Elec. Eng.*, Vol. 13, p. 157.

(32) Economy in Primary Batteries Employed for Generating Power. *Elec. Eng.*, Vol. 13, pp. 326-329.

(33) Measurements of the Hysteretic Loss of Magnetic Energy in Nickel. *Electrician*, Vol. 28, pp. 666-667. Also *Elec. Eng.*, Vol. 13, pp. 349-350.

(34) Ampere-centimeter, a Measure of Electromagnetism. *Elec. World*, Vol. 19, p. 378.

(35) Physics of Cataphoresis. *Elec. World*, Vol. 20, p. 294.

(36) Problem of Eccentric Cylinders. *Elec. World*, Vol. 20, p. 338.

(37) A Differential Wattmeter for Alternating Currents. *Elec. Eng.*, Vol. 14, pp. 596-597. Also *Electrician*, Vol. 29, pp. 300-301.

*1893*

(38) Rectangular Wave Type of Alternating Currents. *Elec. World*, Vol. 21, pp. 203 and 261.

(39) Impedance. *Trans. Amer. Inst. Elec. Engs.*, Vol. 10, pp. 175-216.

(40) Proposed Practical Magnetic Units. *Elec. World*, Vol. 21, p. 371.

(41) Reminiscences of Sir James Anderson. *Elec. Eng.*, Vol. 15, pp. 569-570.

(42) Effective Alternating Currents and Electromotive Forces. *Elec. World*, Vol. 21, p. 458.

(43) Some Measurements of the Temperature Variation in the Electrical Resistance of a Sample of Copper. (With R. A. Fessenden.)

*Proc. Int Elec. Cong.*, Chicago, pp. 183-195. Also *Electrician*, Vol. 31, p. 624.

(44) On an Improved Form of Instrument for the Measurement of Magnetic Reluctance. *Proc. Int. Elec. Cong.*, Chicago, pp. 252-257.

(45) On the Carrying Capacity of Electric Cables, Submerged, Buried or Suspended in Air. Minutes 9th Annual Meeting Association of Edison Illuminating Companies, pp. 79-92. Also *Elec. Eng.*, Vol. 16, p. 199. Also *Elec. World*, Vol. 22, pp. 183-201.

(46) The Impedance of Mutually Inductive Circuits. *Electrician*, Vol. 31, pp. 699-700. Also *Elec. World*, Vol. 22, p. 306.

(47) On the Distortions of Fine Wires Conducting Rapidly Oscillating Discharges. *Elec. Eng.*, Vol. 16, p. 383.

(48) Current Strengths in Simple Circuits Containing Resistance Inductance and Capacity under Periodic E.M.F.'s of the Rectangular Wave Type. *Elec. World*, Vol. 22, p. 379.

(49) The Origin of the Factor $4\pi$ in the Expression for the Magnetomotive Force of a Coil. *Elec. World*, Vol. 22, p. 426.

(50) The Dying Out of Alternating-Current Waves. *Elec. Eng.*, Vol. 16, p. 526.

*1894*

(51) On the Fall of Pressure in Long Leads Traversed by Alternating Currents. *Electrician*, Vol. 32, pp. 239-240. Also *Elec. World*, Vol. 23, pp. 17-19.

(52) Relative Cost of Distribution by Different Electrical Systems. *Elec. World*, Vol. 23, p. 111.

(53) Bimetallic Telephone Conductors. *Elec. Eng.*, Vol. 17, p. 108.

(54) A Contribution to the Theory of Telephony. *Elec. World*, Vol. 23, p. 208.

(55) On the Probability of Identity between Specific Inductance Capacity and Specific Ether Density. (With E. J. Houston.) *Elec. Eng*, Vol. 17, p. 269. Also *Electrician*, Vol. 32, pp. 606-607.

(56) On Certain New Prefixes Proposed for Physical Unit Magnitudes. (With E. J. Houston.) *Elec. Eng.*, Vol. 17, p. 301. Also *Elec. World*, Vol. 23, p. 466. Also *Electrician*, Vol. 32, p. 667.

(57) On the Proposed Names for the Practical Magnetic Units. (With E. J. Houston.) *Elec. World*, Vol. 23, p. 456.

(58) An Estimate of the Distance to which Niagara Power Can Be Economically Transmitted by Electricity. (With E. J. Houston.) *Elec. Eng.*, Vol. 17, pp. 385-387.

(59) Inductance and Capacity of Suspended Wires. (With E. J. Houston.) *Elec. World*, Vol. 24, pp. 6-7.

(60) Electrodynamic Machinery. (With E. J. Houston.) *Elec. World*, Vol. 24, pp. 50, 123, 149, 174, 205, 259, 289, 309, 337, 362, 398, 444, 468, 496, 520, 546, 597, 644.

(61) Sine Form of Curves of Alternating E.M.F. (With E. J. Houston.) *Elec. World*, Vol. 24, p 154.

(62) On the Resistance Offered by a Medium Contained between Spherical Surfaces and Their Mercatorial Projections. (With E. J. Houston.) *Physical Rev.*, Vol. 2, pp. 143-144.

*1895*

(63) On a Proposed Modification of the Generally Accepted Temperature Coefficient of Resistance of Copper Wire. (With R. A. Fessenden.) *Elec. World*, Vol. 25, p. 196.

(64) Does Execution by Electricity, as Practiced in New York State, Produce Instantaneous, Painless and Absolute Death? (With A. H. Geolet.) *Elec. World*, Vol. 25, p. 197.

(65) A New Method of Measuring Illumination. (With E. J. Houston.) *Elec. Eng.*, Vol. 19, p. 226. Also *Elec. World*, Vol. 25, p. 309.

(66) Resonance in Alternating-Current Lines. (With E. J. Houston.) *Trans Amer. Inst Elec. Engs.*, Vol. 12, pp. 133-169.

(67) Contribution to the Theory of Demagnetization. (With E. J. Houston.) *Elec. World*, Vol. 25, p. 582.

(68) On a Possible Law of Residual Magnetism in Iron and Steel. (With E. J. Houston.) *Elec. World*, Vol. 25, p. 631.

(69) On the Causes Producing Phase Differences in Alternating-Current Circuits. *Elec. World*, Vol. 25, p. 651.

(70) On an Approximate Linear Relation between Coercive Force and Maximum Cyclic Intensity in Iron and Steel. (With E. J. Houston.) *Elec. World*, Vol. 26, p. 543.

(71) Abstract from a Lecture on Electric Heating. A course of thirteen practical talks to the working men of the Edison Electric Light Co., of Philadelphia. pp. 85-88.

*1896*

(72) Mr. Edison's Researches on Roentgen Rays. (With E. J. Houston.) *Elec. World*, Vol. 27, p. 308. Also *Elec. Eng.*, Vol. 21, p 281.

(73) An Instrument for Measuring the Mean Spherical Candlepower of Arc Lamps. (With E. J. Houston.) *Elec. World*, Vol. 27, p. 509.

(74) Electromagnetic Theory of the Inertia of Matter. (With E. J. Houston.) *Elec. World*, Vol. 27, p. 672.

(75) On the Seat of the Electrodynamic Force in Ironclad Armatures. (With E. J. Houston.) *Elec. World*, Vol. 28, p. 3.

(76) Measurement of the Insulation Resistance of Continuous-Current Three-Wire Systems while at Work. (With E. J. Houston.) *Elec. World*, Vol. 28, p. 95.

(77) Measurement of the Insulation Resistance of Street-Railway Cables. (With E. J. Houston.) *Elec. World*, Vol. 28, p. 169.

(78) Mode of Transferring Energy in the Electric Circuit. (With E. J. Houston.) *Elec. World*, Vol. 28, p. 683.

*1897*

(79) On the Measurement of the Insulation Resistance of Continuous Current Three-Wire Systems while at Work. (With E. J. Houston.) *Elec. World*, Vol. 29, pp. 309-310.
(80) The Insulating Medium Surrounding a Conductor; the Real Path of Its Current. (With E. J. Houston.) *Proc. Amer. Phil. Soc.*, Vol. 36, pp. 144-175. Also *Elec. World*, Vol. 29, pp. 421-423.
(81) On the Theory of Electric Oscillations in Mutually Inductive Circuits. (With E. J. Houston.) *Elec. World*, Vol. 30, pp. 35-36.

*1898*

(82) Wireless Telegraphy. (With E. J. Houston.) *Elec. World*, Vol. 31, pp. 17-18.
(83) On a Simple Approximate Method of Determining the Harmonic Components of a Graphically Given Complex Harmonic Wave. (With E. J. Houston.) *Elec. World*, Vol. 31, pp. 580-581.
(84) The Present Status of Electrical Engineering. Presidential Address. *Trans Amer. Inst. Elec. Eng.*, Vol. 15, pp 273-280. Also *Elec. World*, Vol. 32, pp. 34-35.

*1899*

(85) Alternating Currents Twenty-five Years Ago and Today. (With E. J. Houston.) *Elec. World and Engr.*, Vol. 33, pp. 267-268.
(86) On the Determination of Current Strength in Three-Pointed Star Resistance Systems. *Elec. World and Engr.*, Vol. 34, pp. 268-270.
(87) On the Predetermination of the Regulation in Alternating-Current Transformers. *Elec. World and Engr.*, Vol. 34, pp. 343-344.
(88) The Equivalence of Triangles and Three-Pointed Stars in Conducting Networks. *Elec. World and Engr.*, Vol. 34, pp. 413-414.
(89) A Multiple Lightning Flash. *Elec. World and Engr.*, Vol. 34, pp. 651-652.

*1901*

(90) Electrical Energy Direct from Carbon. *Elec. World and Engr.* Vol. 37, pp. 22-24.
(91) The New Edison Storage Battery. *Trans. Amer. Inst. Elec. Eng.*, Vol. 18, pp. 219-230. Also *Elec. World and Engr.*, Vol. 37, pp. 867-869.
(92) Reactance Drop and Reactance Factor of Transformers. *Elec. World and Engr.*, Vol. 38, pp. 92-94.
(93) Surges in Transmission Circuits. *Elec. World and Engr*, Vol. 38, pp. 847-849.

*1902*

(94) On the Elevation of the Electrically-Conducting Strata of the Earth's Atmosphere. *Elec. World and Engr.*, Vol. 39, p. 473.

*1903*

(95) The Progress of Electrical Science During the Year 1902. *Elec. World and Engr.*, Vol. 41, pp. 18-19.

(96) The Electrical Resistance of Bearings. (With C A. Adams.) *Elec. World and Engr.*, Vol. 41, p. 231.

(97) On Electric Conducting Lines of Uniform Conductor and Insulation Resistance in the Steady State. *Harvard Eng. Journ.*, Vol. 2, pp. 135-168

(98) Magnetic Units and Other Subjects that Might Occupy Attention at the Next International Electrical Congress. *Trans. Amer. Inst Elec Engs.*, Vol. 22, pp. 529-536.

(99) On the Mechanism of Electric Power Transmission. *Elec. World and Engr.*, Vol. 42, pp. 673-674.

*1904*

(100) Measurement of the Average Electrical Resistance of Sleeve Joints in Aluminum Conductors. (With F. P. Coffin.) *Harvard Eng. Journ.*, Vol. 2, pp. 286-292.

(101) A Historical Sketch of International Electrical Congresses. *Elec. World and Engr.*, Vol. 43, pp. 467-468.

(102) The Efficiency Curves of Constant Potential Transformers. *Elec. World and Engr.*, Vol. 43, pp. 723-724.

(103) Two Elementary Constructions in Complex Trigonometry. *Harvard Ann. Math.*, Vol. 5, pp. 181-184.

(104) On the Parallel Working of Delta- and Star-Connected Three-Phase Transformers. *Elec. World and Engr.*, Vol. 44, pp. 56-57.

(105) Proceedings of the Chamber of Delegates. Secretary's report. *Proc. Int. Elec. Cong.*, St. Louis.

(106) The Relations of Electrical Engineering to Other Branches of Engineering. *Proc. Cong. Arts & Sci.*, Universal Exposition, St. Louis, Vol. 6, pp. 1-12.

(107) The Alternating-Current Theory of Transmission-Speed Over Submarine Telegraph Cables. Section A, *Proc. Int. Elec. Cong.*, St. Louis, Vol. 1, pp. 1-37.

(108) The Present Status of the Edison Storage Battery. (With S. E. Whiting.) *Proc. Int. Elec. Cong.*, St. Louis, pp. 135-151.

(109) High-Frequency Telephone Circuit Tests. Section G, *Proc. Int. Elec. Cong.*, St. Louis, Vol. 3, pp. 1-20.

*1905*

(110) On Direct-Current Balancers. (With S. E. Whiting.) *Elec. World and Engr.*, Vol. 45, pp. 38-40.

(111) A Working Diagram of the Alternating-Current Synchronous Motor. *Elec. World and Engr.*, Vol. 45, pp. 195-197.

(112) The "Balancer" as Employed in Multiple-Voltage Direct-Current Systems *Harvard Eng. Journ.*, Vol. 3, pp. 257-262.

(113) The Metric System of Weights and Measures. *Pop Sci. Mo*, Vol. 66, pp 319-328.

(114) Some Tests of Tantalum Lamps. (With S. E. Whiting.) *Elec World and Engr.*, Vol. 45, p. 590. Also *Electrician*, Vol. 54, p. 1056

(115) A Diagram of the Circuits of the Dynamotor. (With S. E. Whiting.) *Elec World and Engr.*, Vol. 45, pp. 1024-1025.

(116) On a Method of Potential Regulation Based on the Different Resistance Behavior of Carbon and Tantalum Lamps. (With S. E. Whiting.) *Elec. World and Engr.*, Vol. 46, pp. 20-21.

*1906*

(117) The Harmonic Analysis of the Semicircle and of the Ellipse. *Harvard Ann. Math.*, Second Series, Vol. 7, pp. 49-54.

(118) The Distribution of Pressure and Current over Alternating-Current Circuits. *Harvard Eng. Journ.*, Vol. 4, pp. 149-165, 206-225; Vol. 5, pp. 30-56.

(119) 1905-1906. More lengthy article on the above subject.

(120) A Graphic Method of Determining the Ratio of Speed-Voltage Variation in Shunt Motors. *Elec. World*, Vol. 47, pp. 1298-1300.

(121) The Resistivity Temperature-Coefficient of Copper. *Elec. World*, Vol. 47, pp. 1343-1344.

(122) An Approximate Law of Fatigue in the Speeds of Racing Animals. *Proc., Amer. Acad. Arts & Sci.*, Vol. 42, pp. 275-331.

*1907*

(123) A Brief Theory of the Reduction in the Service Life of Frosted Incandescent Lamps. *Elec. World*, Vol. 49, pp. 987-988.

(124) The Basis of an Effective Education—Culture or Vocation. *School Rev.*, Vol. 15, pp. 340-357.

(125) The Process of Building up the Voltage and Current in a Long Alternating-Current Circuit. *Proc., Amer. Acad. Arts & Sci.*, Vol. 42, pp. 701-715.

(126) The Heating of Copper Wires by Electric Currents. (With E. R. Shepard.) *Proc., Amer. Inst. Elec. Eng.*, Vol. 26, pp. 969-995.

(127) The Frequencies of Flicker at which Variations in Illumination Vanish. (With S. E. Whiting.) *Proc., Nat. Elec. Light Asso.* Also *Elec. World*, Vol. 49, pp. 1208-1209.

(128) A Simple Explanation of Wireless Telegraphy. *Independent*, Vol. 63, pp. 1151-1156.

(129) On an Approximate Measurement, by Electrolytic Means, of the Electrostatic Capacity Between a Vertical Metallic Cylinder and the Ground. (With S. E. Whiting.) *Elec. World*, Vol. 48, pp. 1239-1241.

*1908*

(130) The Expression of Constant and Alternating Continued Fractions in Hyperbolic Functions. *Harvard Ann. Math.*, Second series, Vol. 9, pp. 85-96.
(131) A Rectilinear Graphical Construction of the Spherical Reduction Factor of a Lamp. *Proc. Illum. Eng. Soc.*
(132) A New Graphic Method for Determining the Mean Spherical Intensity of a Lamp by the Length of a Straight Line When the Curve of Mean Meridional Intensity is Given. *Elec. World*, Vol. 51, pp. 645-649.
(133) Some Observations on Photometric Precisions. (With S. E. Whiting.) *Proc., Nat. Elec. Light Assoc.*
(134) Standardization Rules for Stationary Direct-Current Machinery in France, Germany, Great Britain and the United States. *Elec. World*, Vol. 51, pp. 1285-1288.
(135) The Measurement of Rotary Speeds of Dynamo Machines by the Stroboscopic Fork. (With S. E. Whiting.) *Trans., Amer. Inst. Elec. Eng.*, Vol. 27, pp. 631-646.
(136) The Humming Telephone. (With W. L. Upson.) *Proc., Amer. Phil. Soc.*, Vol. 47, pp. 329-365.
(137) Artificial Lines for Continuous Currents in the Steady State. *Proc., Amer. Acad. Arts & Sciences*, Vol. 44, No. 4, pp. 97-130.
(138) Deductions from the Records of Running in the Last Olympiad. *Pop. Sci. Mo.*, Vol. 73, pp. 385-391.
(139) Stroboscopic Measurements of the Alternating-Current Frequency with Electric Lamps. *Elec. World*, Vol. 58, pp. 1393-1394.

*1909*

(140) The Influence of Frequency on the Equivalent Circuits of Alternating-Current Transmission Lines. *Elec. World*, Vol. 53, pp. 211-214.
(141) The Linear Resistance between Parallel Conducting Cylinders in a Medium of Uniform Conductivity. *Proc., Amer. Phil. Soc.*, Vol. 48, pp. 142-165.
(142) The Convection of Heat from Small Copper Wires. (With C. A. Wright and J. S. Van Bylevelt.) *Trans., Amer. Inst. Elec. Eng.*, Vol. 28, pp. 363-393.
(143) A Contribution to the Statistics of International Electrical Engineering Symbology. *Elec. World*, Vol. 54, pp. 374-377.
(144) The Equivalent Circuits of Composite Lines in the Steady State. *Proc., Amer. Acad. Arts & Sci.*, Vol. 45, pp. 31-75.

*1910*

(145) Telegraph-Cable Repairing on a Christmas Day. *Pop. Elec.*, Vol. 2, pp. 780-782.

(146) On the Modifications of Hering's Laws of Furnace Electrodes Introduced by Including Variations in Electric and Thermal Resistivity. *Trans., Amer. Inst. Elec. Eng.*, Vol. 29, pp. 465-481.

(147) Report of the Committee on Nomenclature and Standards of the Illuminating Engineers Society. A. C. Humphreys, Chairman.

(148) Vector Power in Alternating-Current Circuits. *Trans., Amer. Inst. Elec Eng.*, Vol. 29, pp. 1233-1267.

(149) The Physiological Tolerance of Alternating-Current Strengths up to Frequencies of 100,000 Cycles per Second. (With E. F. W. Alexanderson.) *Elec. World*, Vol. 56, pp. 154-156.

(150) Graphic Representations of the Linear Electrostatic Capacity Between Equal Parallel Wires. *Elec. World*, Vol. 56, pp. 1000-1002.

(150a) Electric Heating Phenomena. *Elec. Record*, June, pp. 341-342.

*1911*

(151) Vector Diagrams of Oscillating Current Circuits. *Proc., Amer. Acad. Arts & Sci.*, Vol. 46, pp. 373-421.

(152) The Profession of Illuminating Engineering. A Presidential Inaugural Address *Proc., Illum. Eng. Soc.*

(153) Flicker on Fixed and Rotating Targets. (With G. R. Garter, S. C. Li and E. A. Healey.) *Proc., Illum. Eng. Soc.*, p. 120.

(154) A New and Direct Process of Producing Alternating Current Vector Diagrams Experimentally. (With H. G. Crane and J. W. Davis.) *Elec. World*, Vol. 57, pp. 783-787. Also *Electrician*, Vol. 67, pp. 87-88.

(155) On the Duration of Electrical Contact Between Impacting Spheres. (With Edwin F. Northrup.) *Journ. Franklin Inst.*, Vol. 172, pp. 23-38.

(156) The Rotating Electric Current Field. *Proc., Int. Elec. Congress*, Turin, Vol. 2, 33 pp.

(157) The Relations of Physico-Physiological Research to Illuminating Engineering. *Proc., Illum. Eng. Soc.*

(158) The International Electrical Congress of Turin. *Journ. Franklin Inst.*, Vol. 172, pp. 503-507.

(159) Tables of Hyperbolic Functions in Reference to Long Alternating-Current Transmission Lines. *Trans., Amer. Inst. Elec. Eng.*, Vol. 30, pp. 2495-2506.

*1912*

(160) Tables of Sines and Cosines and Tangents of Hyperbolic Angles. *Harvard Eng. Journ.* (Reprinted from Vol. 2, No. 2, 1903, and Vol. 10, No. 4, 1912.)

(161) Artificial Power-Transmission Line. (With H. Tabossi.) *Elec. World,* Vol. 59, pp. 359-361.

(162) Measurements of Voltage and Current over a Long Artificial Power-Transmission Line at 25 and 60 Cycles per Second. (With F. W Lieberknecht.) *Trans., Amer. Inst. Elec. Eng.,* Vol. 31, pp. 1131-1165.

(163) Report of the Committee on Electrical Measurements and Values. *Proc., Nat. Elec. Light Assn.* 35th Convention, Seattle, Wash. June 10-14. Chairman's Report.

(164) An Investigation of Transmission Line Phenomena by Means of Hyperbolic Functions. *Elec. World,* Vol. 60, pp. 306-311.

(165) The Impedance of Telephone Receivers as Affected by the Motion of Their Diaphragms. (With G. W. Pierce.) *Elec. World,* Vol. 60, pp. 560-565. Also *Proc., Amer. Acad. Arts & Sci.,* Vol. 48, pp. 113-151.

(166) Disturbances of Potential and Current Produced in an Active Conducting Network by the Application of a Leak Load. *Elec. World,* Vol. 60, pp. 1373-1376.

*1913*

(167) The Myriawatt. *Harvard Eng. Journ.,* Vol. 12, pp. 34-35.

(168) Chairman's Report of the Committee on Measurements. *Proc., Nat. Elec. Light Assn.,* 36th Convention, Chicago, June 2-6.

(169) Chairman's Report of the Committee on Resuscitation from Electric Shock. *Proc., Nat. Elec. Light Assn.,* 36th Convention, Chicago, June 2-6.

(170) Progress of Electrical Science in 1912. *Elec. World,* Vol. 61, pp. 3-4.

(171) President-Elect, Ira N. Hollis. *Journ. Worcester Polytech. Inst.,* Vol. 16, pp. 277-282.

(172) Applied Electrical Science in 1913. *Elec. World,* Vol. 63, pp. 6-7.

(173) A Convenient Form of Continuous-Current Artificial Line. *Elec. World,* Vol. 61, pp. 1311-1312.

(174) Test of an Artificial Aerial Telephone Line at a Frequency of 750 Cycles per Second. (With F. W. Lieberknecht.) *Trans., Amer. Inst. Elec. Engr.,* Vol. 32, pp. 1283-1303.

(175) The Daylight Effect in Radio Telegraphy. *Proc., Inst. Radio Engr.,* Vol. 1, pp. 39-52.

*1914*

(176) The Influence of Atmospheric Pressure upon the Forced Thermal Convection from Small Electrically Heated Platinum Wires. (With H. S. Sanborn.) *Proc., Amer. Phil. Soc.,* Vol. 53, pp. 55-57.

(177) Report of Committee on International Measurements and Values. *Proc., Nat. Elec. Light Assn.*, 37th Convention, Philadelphia, June 1-5.

(178) Model for Alternating Current Quantities. (With H. G. Crane.) *Elec. World*, Vol. 64, pp. 76-78.

(179) Resonance Tests of Long Transmission Line. (With Harold Pender.) *Elec. World*, Vol. 64, pp. 278-282.

(180) The Computation of Composite Alternating-Current Lines. *Journ., Franklin Inst.*, Vol. 179, pp. 287-297.

(181) An Approximate Uniform Photometric Point Source. (With R. W. Chadbourn and G. D. Edwards.) *Trans., Illum. Eng. Soc.*, Vol. 1, pp. 126-133.

*1915*

(182) Applied Electrical Science in 1914. *Elec. World*, Vol. 65, p. 4.

(183) Hazards from Lightning. *Report of Special Committee, American Institute of Electrical Engineers.* (See also 196.)

(184) Explorations over the Vibrating Surfaces of Telephonic Diaphragms under Simple Impressed Tones. (With H. O. Taylor.) *Proc., Amer. Phil. Soc*, Vol. 54, pp. 96-136.

(185) The Work of the Standards Committee and Its Capability for Usefulness to the Institute Members. *Proc., Amer. Inst. Elec. Eng.*

(186) Thermal Insulation Tests of Electrical Ovens. (With F D. Everett and A. A. Prior.) *Elec. World*, Vol. 65, p. 779. Also *Electrician*, Vol. 75.

(187) Producing Vector Diagrams Experimentally. (With H. G. Crane.) *Elec. World*, Vol. 65, p. 985.

(188) The Receiving End Impedance of a Conducting Line Loaded at Both Ends. *Elec. World*, Vol. 66, pp. 182-184. Also *Electrician*, Vol. 75, pp. 761-762.

(189) Experimental Researches on Skin Effect in Conductors. (With F. A. Laws and P. H. Pierce.) *Proc., Amer. Inst. Elec. Eng.*, Vol. 34, pp. 1953-2021.

(190) The Impedances, Angular Velocities and Frequencies of Oscillating-Current Circuits. *Proc., Inst. Radio Eng.*, 32 pp.

(191) The Mechanics of Telephone-Receiver Diaphragms, as Derived from Their Motional-Impedance Circles. (With H. A. Affel.) *Proc., Amer. Acad. Arts & Sci.*, Vol. 51, pp. 421-482.

*1916*

(192) Notes from the Research Division of the Electrical Engineering Department. *Mass. Inst. Tech. Mon.*, pp. 24-29.

(193) The Development of Applied Science in 1915. *Elec. World*, Vol. 67, pp. 18.

(194) Response to Mayor Mitchel's Address of Welcome. *Proc., Illum. Eng. Soc.*, pp. 591-592.

(195) Memorandum on Opportunities for the Franklin Institute in Connection with American Laboratories. *Journ., Franklin Inst.*, Vol. 181, pp. 401-404.
(196) Lightning, Its Risks and How to Avoid Them. (With Elihu Thomson, C. A. Adams, Louis Bell and D. C. Jackson.) *Gen. Elec. Rev.*, Vol. 19, No. 3, pp. 166-172.
(197) The Telephone and Telephone Exchange, by J. E. Kingsbury. Signed review, *Science*, Vol. 48, pp. 603-604.
(198) Some Properties of Vibrating Telephone Diaphragms. (With H. O. Taylor.) *Proc., Amer. Phil. Soc.*, Vol. 55, pp. 415-460.
(199) Chairman's Report of Committee on Electrical Measurements, Values and Terminology. *National Electric Light Association*, Chicago Convention Pp. 1-8.
(200) Formulas for Lines with Uniform Leak Loads. *Elec. Rev. and Western Elec.*, June 24.
(201) Tractive Resistances to a Motor Delivery Wagon on Different Roads and at Different Speeds. (With O. R. Schurig.) *Trans., Amer. Inst. Elec. Eng.*, Vol. 35, pp. 925-955.
(202) Experimental Researches on Skin Effect in Steel Rails. (With F. H. Achard and A. S. Dana.) Received the Longstreth Medal of the Franklin Institute. *Journ., Franklin Inst.*, Vol. 182, pp. 135-139.
(203) Skin Effect Resistance Measurements of Conductors at Radio Frequencies up to 100,000 Cycles per Second. (With H. A. Affel.) President's Address. *Proc., Inst. Radio Eng.*, pp. 523-574.

*1917*

(204) The Relation of Engineering Education to National Development. *Elec. World*, Vol. 69, pp. 18-19.
(205) Report of Sub-committee on Engineering. *Science*, Vol. 45, pp. 231-233.
(206) The Adoption of the Metric System in the United States. The Metric System from the Standpoint of Electrical Engineering. *Sci. Mon.*, Vol. 4, pp. 193-196.
(207) Recent Investigations of Tractive Resistance to Motor Trucks on Roads and Pavements. (With O. R. Schurig.) *Science*, Vol. 45, pp. 341-343.
(208) The International Metric System in Relation to the Publications of the National Electric Light Association. *Report of the N.E. L.A. Convention*, Atlantic City, May 28-June 1. pp. 1-9.
(209) The American Metric Association. *Oregon Soc. Eng. Bull.*, No. 18, pp. 2-4.
(210) The Horsepower Race. *Sci. Amer.*, Vol. 117, pp. 12 and 16.
(211) Industrial Research and the Colleges. *Trans., Amer. Inst. Elec. Eng.*, Vol. 36, pp. 833-839.

(212) Notes from the Research Division Electrical Engineering Department, Massachusetts Institute of Technology. *Journ. Franklin Inst.*

| | Vol. | pp. |
|---|---|---|
| Tractive Resistance to a Motor-Delivery Wagon... | 183 | 237-8 |
| Skin-Effect Resistance Measurements ............ | 183 | 509-11 |
| Improvement in Hot-Wire Anemometers ........ | 183 | 783-5 |
| Convection of Heat from Small Copper Wires.... | 184 | 115-7 |
| Experiments Towards Determining the Maximum Power of Athletes ......................... | 184 | 313-5 |
| Some Experiments on the Effects of Changes in Diaphragm Thickness on the Characteristics of a Telephone Receiver ........................ | 184 | 723-6 |
| Edge Effect in Copper Bars at Electric Lighting Frequencies ................................ | 185 | 417-9 |

(213) Apparent Dielectric Strength of Varnished Cambric. (With R. J. Wiseman.) *Elec. World*, Vol. 70, p. 1138. Also *M.I.T. Res. Bull.*, No. 15.

(214) Magnetic Flux Distribution in Annular Steel Laminae. (With P. L. Alger.) *Proc., Amer. Inst. Elec. Eng*, pp. 999-1017.

*1918*

(215) Engineering Training at Harvard. *Harvard Alumni Bull.*, pp. 447-449.

(216) Transmission Line Computations. *Elec. World*, Vol. 71.

*1919*

(217) Electromagnetic Theory of the Telephone Receiver. (With H. Nukiyama.) *Proc. Amer. Inst. Elec. Eng.*, pp. 491-539.

(218) A New Geometrical Model for the Orthogonal Projection of the Cosines and Sines of Complex Angles. *Proc. Amer. Acad. Arts & Sci.*, Vol. 54, pp. 371-378.

(219) Alternating-Current Planevector Potentiometer Measurements at Telephonic Frequencies. (With Edy Velander.) *Proc. Amer. Phil. Soc.*, Vol. 58, pp. 97-132.

(220) The Speed of Electricity. *Wireless Age.*, Vol. 46, No. 1.

(221) A Rectangular Component Two-Dimensional Alternating-Current Potentiometer. (With Edy Velander.) *Journ. Franklin Inst.*, Vol. 188, pp. 1-26.

*1920*

(222) Oscillographs and Their Tests. (With R. N. Hunter and A. A. Prior.) *Proc. Amer. Inst. Elec. Eng.* (delivered Dec. 1919), pp. 1-45.

(223) Scientific Research in Engineering Schools. *Elec. World,* Vol. 75, pp. 150-151.
(224) Advances in Signalling Contributed During the War. *New World of Science.* The Century Co., N. Y., pp. 221-246.
(225) Hundredth Anniversary of Electromagnetism, Centennial of the Union of Electricity and Magnetism. *Electrical World,* Vol. 76, p. 736.

*1921*

(226) Research in Engineering Colleges. *Trans Royal Canadian Inst.,* Vol. 13, pp. 49-69.
(227) Putting Electromagnetism on the Job. *Boston Evening Transcript,* Jan. 26.
(228) Report of the Committee on Degrees. (With others.) *Proc. Soc. Promotion Eng. Educ.,* Vol. 28, pp. 362-363.
(229) The Development of Electromagnetism during the Last Hundred Years. *Amer. Hist. Assn. Ann. Rept, 1920,* pp. 273-282.
(230) Research Narrative No. 1, Isolated Research, Its Handicaps. The Story of Mendelism. *Eng. Foundation Pub.,* Vol 1., 2 pp.
(231) The Transient Process of Establishing a Steadily Alternating Current on a Long Line from Laboratory Measurements on an Artificial Line. (With U. Nabeshima.) *Proc. Amer. Phil. Soc.,* Vol. 59, pp. 325-370.
(232) Acoustic Impedance and Its Measurement. (With K. Kurokawa.) *Proc. Amer. Acad Arts & Sci,* Vol. 56, pp. 1-42.
(233) A Mechanical Frequency-Meter of Telephonic Range. (With H. Manneback.) *Journ. Franklin Inst.,* Vol. 192, pp. 349-359.

*1922*

(234) Les Phénomènes physiques le long des fils téléphoniques.
(235) Le Récepteur téléphonique considéré comme un moteur.
(236) Les Applications élémentaires des fonctions hyberboliques à la science de l'ingénieur électricien. Paris, Gauthier-Villars. 153 pp.
(237) A Modern Mecca. *Scientific Mo.,* Vol. 15, pp. 571-580.
(238) On the Education of Engineers in France. *Eng. Educ.,* Vol. 13, pp. 89-118.

*1923*

(239) Dissymmetrical Electrical Conducting Networks. *Journ. Amer. Inst. Elec. Eng.,* Vol. 42, pp. 112-122.
(240) The Paris Observatory and Its Influence on the World. *Harvard Graduates Mag.,* Vol. 31, pp. 335-340.
(241) Text of the Charter of the Académie royale de Belgique, Translated from the original in the archives of the Académie at Brussels. *Proc. Amer. Acad. Arts & Sci.,* Vol. 58, pp. 349-351.

(242) Chart Atlas and Tables of Complex Hyperbolic and Circular Functions. Harvard Univ. Press.
(243) On the Constant Ratio of Mean-to-Mid Potential or Current at Successive Equidistant Points along a Uniform Electric Conducting Line, Real or Artificial, in the Steady State. *Proc. Nat. Acad. Sci.*, Vol. 9, pp. 215-221.
(244) Louis Bell, In Memoriam. 1864-1923. *Trans. Illum. Eng. Soc.*, Vol. 18, pp 7-14.
(245) Bessel or Negative Semi-Imaginary Argument. Section A, B. A. Liverpool Meeting Report of Committee on Calculation of Mathematical Tables. Part III, pp. 7-12.

*1924*

(246) The Reluctivity of the Recently Discovered Magnetic Metal, Permalloy. *Journ. Franklin Inst.*, Vol. 197, pp. 623-628.
(247) Charles Proteus Steinmetz and Complex Quantities. (With E. W. Rice, Jr.) *Gen Elec. Rev.*, Vol. 27, pp. 132-133.
(248) Some Properties of Simple Electric Conducting Networks. *Proc. Amer. Phil. Soc.*, Vol. 63, pp. 171-189.
(249) Some Properties of Three-Terminal Electrical Conducting Networks. *Proc. Amer. Acad. Arts & Sci.*, Vol. 59, pp. 297-311.
(250) International Standardisation in the Field of Power. Section N, First World Power Conference, Wembley.
(251) Kelvin Memorial Address for the American Institute of Electrical Engineers. *Kelvin Centenary Celebration*, p. 91, also pp. 48-51.
(252) Hyperbolic-Function Series of Integral Numbers and the Occasions for Their Occurrence in Electrical Engineering. *Proc. Int. Math. Congress*, Toronto, Section IVa, pp. 441-459.
(253) Dr. Kennelly on the Centenary Celebration of the Franklin Institute. *Elec. World*, Vol. 84, p. 793.
(254) Time Constants for Engineering Purposes in Simple Exponential Transient Phenomena. *Proc. Nat. Acad. Sci.*, Vol. 10, pp. 468-473.
(255) The Conference in Relation to Amateur Activities. *Q.S.T.*, Vol. 8, pp. 18-19.
(256) The Rumford Fund. *Science*, Vol. 60, pp. 558-559.
(257) The Field of a Technical Journal. *Elec. World*, Vol. 84, 50th Anniversary Number, pp. 569-571.

*1925*

(258) Research Narrative No. 100.—A Retrospect in Research. *Eng. Foundation Pub.*
(259) The Thermal Time-Constants of Dynamo-Electric Machines. *Journ. Amer. Inst. Elec. Eng.*, Midwinter Convention, pp. 1-11.
(260) Louis Bell, 1864-1923. *Proc. Amer. Acad. Arts & Sci.*, Vol. 59, pp. 633-639.

(261) Charles Proteus Steinmetz (1865-1923). *Proc. Amer. Acad. Arts & Sci.*, Vol. 59, pp. 657-661.
(262) The Motional Impedance of an Electrodynamic Loud Speaker. *Q.S.T.*, Vol. 9, pp. 35-37.
(263) Identical Electrical Networks in Series. *Proc. Amer. Phil. Soc.*, Vol. 64., pp. 1-16.
(264) The Measurement of Acoustic Impedance with the Aid of the Telephone Receiver. *Journ. Franklin Inst.*, Vol. 200, pp. 467-489.
(265) George Chandler Whipple (1866-1924). *Proc. Amer. Acad. Arts & Sci.*, Vol. 60, pp. 654-657.
(266) Telegraph Cable Repairing on a Christmas Day. *Zodiac*, Vol. 18, pp. 152-154.
(267) Computation of the Behavior of Electric Filters under Load. (With A. Slepian.) *Proc. Amer. Acad. Arts & Sci.*, Vol. 60, pp. 461-483.

*1926*

(268) The Advancement of Engineering in Relation to the Advancement of Science. Address of Chairman Section M, American Association for the Advancement of Science, Kansas City, Dec. 1925. *Science*, Vol. 63, pp. 25-29. Also *Nature*, Vol. 117, pp. 160-162.
(269) The Rumford Fund. *Science*, Vol. 63, p. 223.
(270) Can the Thermal Capacity of Electric Machines Be Made a Simple and Practical Element of Rating? *Journal Amer. Inst. Elec. Eng.*, Vol. 45, pp. 1-11. I.E.C. paper, pp. 1-8, also French translation.
(271) La Capacité thermique des machines électriques, peut-elle être un élément simple et pratique pour en déterminer la puissance? (French translation of 244.) I.E.C. paper, pp. 1-11.
(272) The Fourth American Radio Congress. *Harvard Grad Mag.*, Vol. 34, pp. 357-360.
(273) Reports of Ether-Drift Measurements. *Elec. World*, Vol. 87, pp. 1045-1047.
(274) Address of A. E. Kennelly at the Presentation of the John Fritz Medal to Edward Dean Adams, Engineering Building, N. Y. Published by E. D. Adams.
(275) Testimony before Congressional Committee on the Adoption of the Metric System. *Congressional Digest*, Vol. 5, pp. 132, 133, 137 and 138.
(276) Equiangular Spiral Polygons as Presenting Themselves in Electrical Engineering. *Proc., Amer. Phil. Soc.*, Vol. 65, pp. 326-348.
(277) Changes during the Last Twenty Years in the World's Speed Records of Racing Animals. *Proc., Amer. Acad. Arts and Sci.*, Vol. 61, pp. 487-523.
(278) The Interrupted Long Slice. *Zodiac*, Vol. 18, pp. 328-331.

(279) Historical Note on the Direction of Polarity in the Conventional Symbol for Voltaic Batteries. I E.C. Document, distributed abroad.

(280) Meeting of British Association at Oxford. *Elec. World,* Vol. 88, p. 476.

(281) The Metric System of Weights and Measures. *Sci. Mo.,* Vol. 23, pp. 549-551, Vol. 26, pp. 147-149, 1928.

(282) Dec. 1926 and Jan. 1927. Two Lectures on the Applications of Hyperbolic Functions to Electrical Engineering, before the Istituto Fisico di Roma, abstract published in *Pub. Math. Dept. University of Rome.*

*1927*

(283) The Danger of Electric Shock from the Electrical Engineering Standpoint. *Phys. Therap.,* Vol. 45, pp. 16-23.

(284) Computation of the Unbalance Factor of a Three-Phase Triangle when the Lengths of Three Sides are Given. *Jour., Amer. Inst. Elec. Eng.,* pp. 240-241.

(285) The Acoustic Impedance of Straight Cylindrical Air Columns in Brass Tubes. (With R. P. Siskind.) *Proc., Amer. Phil. Soc.,* Vol. 66, pp. 89-133.

(286) Address in Italian on "The Discoveries of Alessandro Volta and their Subsequent Development." "Le Scoperte di Alessandro Volta ed il loro successivo sviluppo," to the University of Padua, published in the *Engineering Journal of the University of Padua.*

(287) Lectures on "The Applications of Hyperbolic Functions to Electrical Engineering Problems." Faculty of Sciences, University of Rome.

(288) The Application of Hyperbolic Functions to Recent Developments in Submarine Telegraphy. Paper presented to the Volta Int. Congr. Teleg. and Tel., Como, Sept. 10-15.

(289) Address made during the Celebration of Alessandro Volta by the International Congress of Physicists and the I.E.C. at Como. *Proc. Volta Int. Cong. Phys.* Vol. 1, pp. 23-30.

(290) Normal Attenuation in Electrical Conducting Networks. *Proc. Volt. Int. Cong. Phys.,* Como, Sept. 10-15. Vol. 1, pp. 215-43.

*1928*

(291) A Method for Determining the Constants of an Electromagnetic Oscillograph. *Proc., Amer. Phil. Soc.,* Vol. 67, pp. 123-128.

(292) Historical Outline of the Electrical Units. Two lectures before the Conference of Teachers of Electrical Engineering, Pittsburgh. *Journ. Eng. Educ.* Vol. 19, pp. 229-275.

(293) Gudermannian Complex Angles. *Proc., Nat. Acad. Sc.,* Vol. 14, pp. 839-844.

*1929*

(294) Revision of appendix "On the Relative Values of the Windings of Electromagnetic Coils," for new edition of R. Varley's "The Electro-Magnet," N. Y., 1920.

(295) Revision of First Section on Units of "Standard Handbook for Electrical Engineers." McGraw-Hill Book Co.

(296) Electricity in the Household. *Scribner's Mag.*, Vol. 85, pp. 452-459.

(297) Recent Technical Developments in Radio. *Annals, Amer. Acad Pol. and Soc. Sci.*, Vol. 142, pp. 1-9.

(298) Meteorological Units Adopted by Various Countries. *Measurement*, Vol 4, no. 2, pp. 4-5.

(299) Gudermannians and Lambertians with Their Respective Addition Theorems. *Proc., Amer. Phil. Soc.*, Vol. 68, p. 1029.

(300) Current Developments in Radio Research Cooperation. Report from Cooperation Committee U.R.S.I. to American Section, Washington, pp. 1-4.

(301) Three-Terminal Alternating-Current Electrically-Conducting Net. Nat. Acad. Sci. Report, *Science*, Vol. 69, p. 530.

(302) Alternating Current Nets. *Proc., Amer. Acad. Arts and Sci.*, Vol. 64, pp. 1-18.

(303) The Bar at Bilbao. A Reminiscence of Cable Repairing in the Bay of Biscay. *Zodiac*, Vol. 22, pp. 45-47.

*1930*

(304) Magnetic Circuit Units. Proc., Winter Convention, American Institute of Electrical Engineers. *Trans. Amer. Inst. Elec. Eng.*, Vol. 49, pp. 486-510.

(305) The Laws of Fatigue in Racing. *Tech. Eng. News*, Feb. 1930, pp. 12-13, 22, 24.

(306) Recent Progress of the Metric System in the United States. American Association for the Advancement of Science address at Des Moines. *Measurement*, Vol. 5, No. 1, pp. 1-4.

(307) Papers presented at the Des Moines Meeting. *Science Service* and *Science*, Vol. 71, No. 1832.

(308) Parallel Connections of Identical Nets. *Proc., Amer. Phil. Soc.*, Vol. 69, pp. 161-173.

(309) The Program of the Cooperation Committee. Report to the American Section, URSI.

(310) Solar Eclipse Radio Phenomena. *Electronics*.

(311) A propos des quadripoles et filtres. (Traduit par M. Pomey.) *Revue Générale de l'Electricité*, Vol. 27, p. 962.

(312) Examples from Daily Life Illustrating Waste of Time Involved in Adherence to our Antiquated System of Weights and Measures. *Measurement*, Vol. 5, No. 3, pp. 1-3.

(313) Cooperation Committee Program. *Proc., I.R.E.,* Vol. 18, pp. 1430-1432.
(314) The Rumford Fund. *Science,* Vol. 72, p. 605.
(315) Unités et définitions adoptées par l'Assemblée plénière de la Commission électrotechnique internationale tenue en Scandinavie en 1930. (Traduit par L. Vellard.) *Revue Générale de l'Electricité,* Vol. 28, pp. 719-722.

*1931*

(316) Units and Definitions Adopted by the International Electrotechnical Commission. *Elec. Eng.,* Vol. 50, pp. 141-142.
(317) Recent Progress of the Metric System in the United States. *Measurement,* Vol 6, No. 1, pp. 1-6.
(318) Magnetic-Circuit Units as Adopted by the I.E.C. *Trans. Amer. Inst. Elec. Eng.,* Winter Convention 1931, pp. 1-5.
(319) The Convention of Equidimensional Electric and Magnetic Units. *Proc. Nat. Acad. Sci.,* Vol. 17, pp. 147-153.
(320) The Equidimensional Convention for Electromagnetic Units. *Science,* Vol. 73, p. 535.
(321) Rationalised versus Unrationalised Practical Electromagnetic Units. *Proc. Amer. Phil. Soc.,* Vol. 70, pp. 103-119.
(322) Report of Cooperation Committee for Year 1930-1931. (With others.)
(323) Report of Commission No. 4 on Liaison. *Proc. U.R.S.I.,* 1931.
(324) Report of the Special Committee on Membership. (With others.) Amer. Acad. Arts and Sci., April Meeting 1931.
(325) The Oersted Considered as a New International Magnetic Unit. *Sci. Mo.,* Vol. 32, pp. 378-380.
(326) Radio and Research. Radio talk presented May 1, 1931, under the auspices of Science Service, Washington, D. C., over the Columbia Broadcasting System.
(327) The Modern Electric Age in Relation to Faraday's Discovery of Electromagnetic Induction. *Nature,* Vol. 128, pp. 356-359.
(328) The Present Status of Complex Angles in Their Applications to Electrical Engineering. *Inst. Elec. Eng. Japan,* pp. 1-44.
(329) The Present Status of Magnetic-Circuit Units. *Inst. Elec. Eng. Japan,* pp. 1-25.
(330) The Concept of Beauty as Related to Engineering. *Inst. Elec. Eng. Japan,* pp. 1-19.
(331) Notes on the Progress of the Metric System in Japan. *Measurement,* Vol. 6, No. 4, pp. 1-3.
(332) Considerations That Led to the Suggestion of the Existence of an Ionised Layer in the Atmosphere. *Radio no Nippon,* Feb. 1932.

(333) Le Programme du Cooperation Committee. *Comptes Rendus de l'Assemblée de Stockholm Union Géodesique et Géophysique Internationale, Section de Magnétisme et Electricité Terrestres. Bulletin*, No. 8, pp. 419-422.
(334) Cosmic Phenomena Influencing the Propagation of Radio Waves. *Ibid.*, pp. 422-437.

*1932*

(335) Note sur les décisions prises par la Sous-Commission des Grandeurs et Unités électriques et magnétiques de la Commission électrotechnique internationale à la réunion de Londres de Septembre 1931. *Revue Générale de l'Electricité*, Vol. 31, No. 1, pp. 7-11.
(336) Recent Developments in Magnetic Units. Based in part on the minutes of the London 1931 meeting of the International Electrotechnical Commission. *Elec. Eng.*, Vol. 49.
(337) Actions of Electrotechnical Commission on Names for Metric Magnetic Units *ASA Bull.*, Vol. 3, p 183.
(338) L'Enseignement de l'électricité aux Etats-Unis. Congrès International d'Electricité, Paris, 1932. Section 13, July 4-11.
(339) Cosmic Disturbances of the Earth's Magnetic Field and Their Influence upon Radio Communication. *Sci. Mo.*, Vol. 35, pp. 42-56.
(340) Cosmic Disturbances of the Earth's Magnetic Field and Their Influence upon Radio Communication. (Somewhat different from No. 339.) Carnegie Institution of Washington Supplementary Publication No. 5. Lecture delivered at the Carnegie Institution, March 1932.
(341) The International Electrical Congress at Paris. *Sci. Mo.*, Vol. 35, pp. 377-379.
(342) The Work of Joseph Henry in Relation to Applied Science and Engineering. Second Joseph Henry Lecture delivered before the Philosophical Society of Washington, April 23, 1932. *Science*, Vol. 76, pp. 1-7. Also in *Journ., Wash. Acad. Sci.*, Vol. 22, pp. 293-310.
(343) Radio during Solar Eclipses. *Electronics*.
(344) Science Service Conference article. *Science*, Vol. 76, pp. 180-181.
(345) Memorandum to Committee on Liaison, No. 4, URSI on measurements recorded of ionised-layer height changes during solar eclipse of August 31, 1932.
(346) Standardisation of Metric Magnetic Units. *Industrial Standardisation*, Nov. 1932, pp. 284-5.

*1933*

(347) International Radio Tuning at Long Range. *Sci. Mo.*, Vol. 36, pp. 144-146.

(348) Recent Actions Taken by the Symbols, Units and Nomenclature (S. U. N.) Committee of the International Union of Pure and Applied Physics, in Reference to CGS Magnetic Units. A.I.E.E. Mid-Winter Convention, Jan. 23-27, 1933.

(349) Memorandum on Magnetic Units suggesting modifications based on recommendations of the International Electrotechnical Commission in 1930-31 and of the International Union of Pure and Applied Physics in 1932. 3 pp. photostated.

(350) Conference of the Symbols, Units and Nomenclature Commission of the International Union of Pure and Applied Physics at Paris, in July 1932 and Its Results. *Proc., Nat. Acad. Sci.*, Vol. 19, pp 144-149.

(351) Revision of First Section of "Standard Handbook for Electrical Engineers," 6th edition, 1933. McGraw-Hill Book Company.

(352) Notes on the July 1932 Meeting of the Committee on Symbols, Units, and Nomenclature of the International Union of Pure and Applied Physics to Discuss Magnetic Units. *Terres. Mag. and Atmos Elec.*, Vol. 37, pp. 447-453.

(353) Reprints Nos. 348, 350, and 352 bound in red cover.

(354) Magnetic Definitions from the Circuital Standpoint. Read April 22, 1933 at American Philosophic Society Meeting, Philadelphia. *Proc. Amer. Phil. Soc.*, Vol. 72, pp. 39-95.

(355) Possible Extensions of the Existing International Series of Electric Units (Ohm, Volt, Ampere, Coulomb, Farad, Henry, Joule, and Watt) into a Complete Absolute System. Read at Chicago joint meeting of A.A.A.S., A.P.S. and Am. Section of the S.U.N. June 24, 1933. *Bull 93*, Nat. Res. Council, pp. 94-112.

(356) An International System of Physical Units and the Teaching of Such Units to American Students. *Amer. Phys. Teacher*, Vol. 1, pp. 74-81.

(357) Biographical Memoir of Thomas Alva Edison. *Biog. Memoirs, Nat. Acad. Sci.*, Vol. 15, Tenth Memoir, pp. 287-304.

(358) Samuel Wesley Stratton. Obituaire pour Bureau international des Poids et Mesures.

*1934*

(359) International Standards for Electric and Magnetic Magnitudes and Units. *Industrial Standardization*, Vol. 5, Feb. 1934.

(360) The Metric System of Weights and Measures in Relation to Instruments. *Instruments*, Vol. 7, p. 25.

(361) Actions on Electric and Magnetic Units. *Elec. Eng.*, Vol. 53, p. 402.

(362) Note sur les résolutions adoptées par la Section B des Grandeurs et Unités électriques et magnétiques du Comité d'Etudes No. 1 de la Nomenclature (Paris 5 and 6 octobre, 1933). *Revue Générale de l'Electricité*, March 3, 1934, p. 267.

(363) 20th Anniversary Greeting to American Radio Relay League. *Q. S. T.*, Vol. 18, No. 5.
(364) The Work of the Institute in Standardization. *Elec. Eng.*, Vol. 53, pp. 676-680.
(365) Obituary of George Owen Squier. *Science*, Vol. 79, pp 470-471.
(366) Twentieth Anniversary of American Radio Relay League. *Q.S.T.*, Vol. 18, No. 5.

*1935*

(367) Recent Actions of the International Electrotechnical Commission in Reference to Electric and Magnetic Units. *Amer Phys. Teacher*, Vol. 3, pp. 89-90.
(368) Proposed Reforms of the Gregorian Calendar. *Proc., Amer. Phil. Soc.*, Vol. 75, pp. 71-110.
(369) History of our Calendar. *Journ. Calendar Reform*, October, 1935, pp. 134-142.
(370) Actions of the International Electrotechnical Commission (I. E. C.) at the June 1935 Meetings in The Hague and Brussels, concerning Electrical Units. A S. A. Press Release, August 1935.
(371) Porthcurno Days in 1876. *Zodiac*, Vol. 28, pp. 68-69.
(372) Adoption of the Meter-Kilogram-Mass-Second (MKS) Absolute System of Practical Units by the International Electrotechnical Commission (I. E. C.) Bruxelles, June 1935. *Proc. Nat. Acad. Sci.*, Vol. 21, pp. 579-583.
(373) Memorandum sur le System MKS. *Procès Verbaux, Comité consultatif d'Electricité Paris, 1935.* 2ᵉ Série, Vol. 17, pp. 325-330.
(374) Propositions au Comité Consultatif d'Electricité et au Comité International des Poids et Mesures. *Procès Verbaux des Séances, Paris, 1935.* 2ᵉ Série, Vol. 17, pp. 137-144.
(375) I. E. C. Adopts MKS System of Units. *Elec. Eng.*, Vol. 54, pp. 1373-1384.

*1936*

(376) Adoption par la Commission Electrotechnique Internationale du Systéme Giorgi d'Unités MKS, Juin, 1935. *Bulletin de la Société francaise des Electriciens*, pp. 47-80.
(377) The MKS System of Units. *Jour. Inst. Elec. Eng.*, Vol. 78, pp. 235-244.
(378) Oliver Heaviside (1850-1925). *Proc., Amer. Acad. Arts and Sci.*, Vol. 70, pp. 544-545.
(379) Magnetic Formulae Expressed in the MKS System of Units. *Proc., Amer. Phil. Soc.*, Vol. 76, pp. 343-377.
(380) The Adoption of the Giorgi MKS Absolute System of Practical Units by the International Electrotechnical Commission (I. E. C.) June 1935. *Trans., Illum. Eng. Soc.*, Vol. 31, pp. 685-693.

(381) Samuel Wesley Stratton (1861-1931). *Biog Memoirs, Nat. Acad. Sci*, Vol. 17, pp. 253-260.

(382) The MKS System of Giorgi as Adopted by the International Electrotechnical Commission (I. E. C.) in June 1935 *Jour. Eng. Educ.*, Vol. 27, pp. 290-307.

*1937*

(383) Elihu Thomson. *Elec. Eng.*, Vol. 56, p. 436.

(384) Elihu Thomson. *Sci. Mo.*, Vol. 44, pp. 474-476.

(385) The U.R.S.I. Programs of Short-Wave Station W1XAL. *Science*, Vol. 85, pp 419-421.

(386) Mechanic Impedance in MKS Units. (With Jackson H. Cook.) Letters to the Editor, *Elec. Eng*, Vol. 56, pp. 1062-1063.

*1938*

(387) Agenda of the Torquay meeting of I. E. C. held the 23rd and 24th of June 1938.

(388) The MKS System of Units Applied to Electroacoustics. (With Jackson H. Cook.) *Jour. Acous. Soc. Amer.*, Vol. 9, pp. 336-341.

(389) Kennelly's Layer. Letters to the Editors, *Life*, Vol. 4, p. 2.

(390) Abstract of Actions taken at Torquay by E. M. M. U. Committee, June 1938.

(391) George Owen Squier (1865-1934). *Biog. Memoirs, Nat. Acad. Sci.*, Vol. 20, 4th Memoir, pp. 151-159.

*1939*

(392) Recent Developments in Electrical Units on E. M. M. U. Actions at Torquay 1938. *Elec. Eng.*, Feb.

Albert Sauveur

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—SIXTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# ALBERT SAUVEUR

1863–1939

BY

REGINALD A. DALY

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1940

# ALBERT SAUVEUR

## 1863–1939

BY REGINALD A. DALY

The nineteenth century was the age of steel; the twentieth begins the age of steels, many and better steels, on the use of which modern industries depend. New alloys of iron and improving methods of their treatment in the furnace have revolutionized the heavy industries and enormously increased the range and efficiency of consumers' goods. That social betterment is largely the product of metallography, and a leader in the development of this science was Albert Sauveur. He was the Dean of American metallographers and a pioneering genius, recognized by the steel manufacturers of the whole world. His works do follow him, for his "Metallography and Heat Treatment of Iron and Steel" is still standard authority on the subject, and his many students continue to spread the influence of Sauveur's fundamental ideas.

Albert Sauveur, born in Louvain, Belgium, on June 21, 1863, was of French blood—the son of Lambert Sauveur (Préfet of the Athénée Royal in that city) and Hortense (Franquin) Sauveur. He was educated at the Athénée Royal; at the Liège School of Mines (1881-1886); and at the Massachusetts Institute of Technology, where, in 1889, he won the degree of Bachelor of Science in Mining and Metallurgy. Immediately after graduation he accepted a position in the chemical laboratory of the Pennsylvania Steel Company at Steelton, Pennsylvania. In his "Metallurgical Reminiscences" (1937) he wrote: "Life in a steel mill chemical laboratory lacks enchantment. I entered it every morning at seven o'clock to leave it at six o'clock. To be sure, on Saturdays we stopped our labor at 5 P. M., but as we had only fifty minutes for refreshment at noon you will see that we worked, if that is the correct way to express it, exactly sixty hours per week.

"While I had been told that I would be paid $50 per month for my services, when my first pay check arrived I found to my disappointment and indignation that it was only for $40. Lest

you infer that a college education was worth very little in those days, you should recall that unskilled labor was being paid $1.00 for ten hours work whereas I received $1.67, from which it follows that a college education was worth sixty-seven cents."

After eighteen months of an unsatisfactory program of work assigned to him at Steelton, he accepted employment in the Bessemer mill of the Illinois Steel Company, South Chicago. He was given a room to himself and supplied with an old-fashioned vertical microscope. With this equipment he was instructed to "study the structure of steel and the ailments to which his flesh is heir." "Five happy years were spent in this way, nearly each day made brighter by what seemed to me a little advance in a research in which I was now deeply interested, which was to continue forty-five years. . . . This early introduction of the microscope into the steel mill laboratory we owe solely to the vision of W. R. Walker, of blessed memory, . . . at the time general manager of the South Works of the Illinois Steel Company." In his "Reminiscences" he also noted that Sorby's classic paper on the microstructure of steel had been published in 1886, and that Osmond and Werth in France and Martens in Germany were also making contributions to the new science. After the year 1891, when Sauveur began his own independent work, he kept in close touch with the American Howe, the English Arnold, Roberts-Austen, Hadfield, and Stead, and the French Le Chatelier—"all stars of the first magnitude in the metallurgical sky."

With his crude microscope he pioneered further, making the first American microphotographs showing the internal structure of steel. Ever since, this method has been profitably used on a wholesale scale. He was soon able to prove to the officials of his steel company that they had been giving the wrong treatment to their metal, and he detailed the proof in his first publication: "The Microstructure of Steel" (1893), a paper later translated into French, German, and Russian. Although he had guided the steel company to a more scientific and effective way of manufacturing steel designed for heavy duty, a new general manager did not understand what Sauveur had done in adding millions of dollars to the company's products, and directed that

the scientific laboratory should be abolished! Sauveur then opened a private laboratory in Boston, and, in 1898, had the courage to begin the publication of a quarterly journal called "Metallographist," later issued under the name "Iron and Steel Magazine." During seven years this journal did much to stimulate interest in the new science. In 1912 he published his "Metallography and Heat Treatment of Iron and Steel," a book now in its fourth edition and with total sale of nearly 20,000 copies. About this time he opened a correspondence course in metallography, with ultimate enrollment of 1500 students. The value of his ideas was clearly shown by the fact that, between 1896 and 1901, ten of the leading steel companies in the United States equipped themselves for the microscopical examination of their many varieties of steel.

Sauveur's principal contributions to the science and art of metallurgy may be summarized under four heads: (1) improvement in the technique of the microphotography of metals, an indispensable method of comparing internal structure and therefore the conditions that control usefulness to man; (2) research on the nature of the constituents of the many alloys, and on the important matter of establishing international nomenclature for those constituents; (3) discovery of the mechanism involved in the tempering of steel, with results so vital to the industry; and (4) prolonged and fruitful study of the effect of heat treatments on the grain, and therefore strength and toughness, of the iron alloys. In the words of Leon Guillet and Albert Portevin, Sauveur was "constructeur et créateur d'outillage métallographique, expérimentateur et savant, éditeur et propagandiste, professeur et éducateur," who "personifia la nouvelle science des métaux sous tous ses aspects et il leur a rendu d'inappréciables services. . . . Son oeuvre restera comme une des plus parfaites expression de l'époque créatrice de l'histoire de la métallurgie scientifique."

In 1899 Sauveur was called to Harvard University, where, in succession, he became: Instructor in Metallurgy (1899-1901); Assistant Professor (1901-1905); Professor (1905-1924); Gordon McKay Professor (1924-1935); Professor Emeritus,

after 1935. During those years he published many technical papers, listed in the following bibliography. His writings, like his university lectures and conversation, were remarkably lucid, proving complete mastery of our language, which he had made his own only after his twenty-third year.

On June 4, 1891, Sauveur was married to Mary Prince Jones of Spencer, Massachusetts. Their children included Albert (deceased), Hortense (now Mrs. Romeyn Taylor), and Mary Isabella (now Mrs. George C. Eaton).

A man of the world, the world has showered honors upon him. His honorary degrees include: Sc.D., Case School of Applied Science, 1921; Sc.D., University of Grenoble, France, 1924; Sc.D., University of San Marcos, Peru, 1925; D. Eng., Lehigh University, 1926; S.D., Harvard University, 1935. In 1919 he was awarded the Elliott Cresson Gold Medal of the Franklin Institute; in 1924, the Bessemer Medal of the Iron and Steel Institute of Great Britain. He was the first recipient of the Albert Sauveur Achievement Medal of the American Society for Metals. Posthumously, the Association of Graduate Engineers of the University of Liège honored him with the Trasenster Medal, and the Franklin Institute honored itself by enrolling Sauveur's name among the men to whom the Franklin Medal has been voted. France and his native Belgium recognized his distinction by electing him Officier of the Légion d'Honneur, Officier d'Académie, and Officier of the Order of Leopold.

Sauveur was a member of the National Academy of Sciences, of the American Academy of Arts and Sciences, of the American Philosophical Society, of the Iron and Steel Institute of Great Britain, the Iron and Steel Institute of America, of Sigma Xi, and of Tau Beta Pi. He was elected to honorary membership in the American Institute of Mining and Metallurgical Engineers, the American Society for Metals, the Society of Engineers of the Liège School of Mines, the Société des Ingénieurs Civils de France, and the Société de l'Industrie Nationale (France); and to corresponding membership in the Société d'Encouragement pour l'Industrie Nationale (France).

During the period 1917-1919 he served as metallurgist for the American Aviation Commission in France, and also as metallurgical expert in the French Ministry of Munitions. In 1924 he was the Henry Marion Howe lecturer to the American Institute of Mining and Metallurgical Engineers; in 1929, Henry de Mille lecturer to the American Society for Steel Testing; in 1938, Marburg lecturer to the American Society for Testing Materials. He was a United States delegate to the Pan-American Scientific Congress at Lima, Peru (1924). For many years he was steadily retained as metallurgical consultant by several large corporations using special steels in the manufacture of factory and domestic tools.

But Albert Sauveur was much more than a master of his craft. Like one of his own steels, his spirit was exquisitely tempered for service among all sorts of men—a spirit of intelligence and cooperation that made for complete happiness in his family, and for the love and respect of students and colleagues alike. His insistence on clearness of thought was coupled with deep sympathy with, and understanding of, all with whom he worked. He "allied French finesse with Anglo-Saxon humor." These inborn graces of the soul and his never-failing, perfect courtesy explain the unique, unforgettable charm of Albert Sauveur. It is a glory for Belgium to have produced him, and for America to have facilitated, however imperfectly, his development as a pioneer in science and as a man who was truly and thoroughly civilized.

## KEY TO ABBREVIATIONS USED IN BIBLIOGRAPHY

Amer. Inst. Min. Eng. = American Institute of Mining Engineers.
Amer. Inst. Min. & Met. Eng. = American Institute of Mining and Metallurgical Engineers.
Amer. Iron & Steel Inst. = American Iron and Steel Institute.
Amer. Phil. Soc. = American Philosophical Society.
Amer. Soc. Metals = American Society for Metals.
Amer. Soc. Steel Treat. = American Society for Steel Treating.
Amer Soc. Test. Mat. = American Society for Testing Materials.
Chem. & Met. Eng = Chemical and Metallurgical Engineers.
Electro. & Met. Ind. = Electrochemical and Metallurgical Industry.
Eng. Mag. = Engineering Magazine.
Eng. & Min. Journ. = Engineering and Mining Journal.
Harvard Eng. Journ. = Harvard Engineering Journal.
Int. Assoc. Test. Mat. = International Association for Testing Materials.
Int. Eng. Cong. = International Engineering Congress.
Iron & Steel Mag. = Iron and Steel Magazine.
Iron Trade Rev. = The Iron Trade Review.
Journ., Iron & Steel Inst. = Journal, Iron and Steel Institute.
Met. & Chem. Eng. = Metallurgical and Chemical Engineering.
Nat. Acad. Sci. = National Academy of Sciences.
Proc. Amer. Soc. Test. Mat. = Proceedings, American Society for Testing Materials.
Proc. Eng. Soc. W. Pa. = Proceedings, Engineers' Society of Western Pennsylvania.
Sci. Amer. = Scientific American.
Tech. Quar. = Technology Quarterly, Massachusetts Institute of Technology.
Trans. Amer. Inst. Min. Eng. = Transactions, American Institute of Mining Engineers.
Trans. Amer. Soc. Min. & Met. Eng. = Transactions, American Society of Mining and Metallurgical Engineers.
Trans. Amer. Soc. Steel Treat. = Transactions, American Society for Steel Treating.

## BIBLIOGRAPHY

*1893*

Microstructure of Steel. *Trans. Amer. Inst. Min. Eng.* XXII, 540-90.
Ferrite and Pearlyte. *Stahl und Eisen* XV, 537-39.

*1895*

The Relations between Temperature and Grain of Steel (with H. M. Howe). *Eng. & Min. Journ.* IV, 537.

*1896*

Further Notes on the Hardening of Steel (with H. M. Howe). *Journ. Iron & Steel Inst.* L, 170-239.
The Microstructure of Steel and the Current Theories of Hardening. *Trans. Amer. Inst. Min. Eng.* XXVI, 853-906.
Notes on the Microstructure of Hardened Steel and the Missing Color Carbon. *Journ. Iron & Steel Inst.* L, 191-99.

*1897*

Microscopic Examination of Iron and Steel. Series of Articles. *Eng. & Min. Journ.* LXII, 662-63, LXIV, 69, 215-16, 517-18.
Prospectus issued by the Boston Testing Laboratories, Boston, Mass.

*1898*

Introduction to "The Metallographist," I. 1.
Editor of "The Metallographist," a quarterly publication devoted to the study of metals. Published by the Boston Testing Laboratories, Boston, Mass.
The Constitution of Steel Considered as an Alloy of Iron and Carbon. *Tech. Quar.* XI, 78-93.

*1899*

The Progress of Metallography in 1898. The Metallographist, II, 1, 1-2.
The Relation Between the Structure of Steel and its Thermal and Mechanical Treatment. *Jour. Iron & Steel Inst.* II.
The Constitution of Hardened Steel. The Metallographist, II, no. 4, 305-314.
The Progress of Metallography in 1898. *The Mineral Industry*, VII, 765-775.
The Mechanical Uses of the Sciences of Metallography. *Eng. Mag.*, Sept., 977-992.
Biographical Sketch, H. H. Howe. *Cassier's Magazine*, Nov.
The Metallographist, II, Edited.

*1900*

The Microstructure of Coke and Charcoal, Pig Irons. The Metallographist, III, 154.
Biographical Sketch, Henry Clifton Sorby. The Metallographist, III, 89.
Biographical Sketch, Adolf Martens. The Metallographist, III, 181.
Soft Steel, Series of Articles in *Boiler Maker and Sheet Metal Worker*, VIII, no. 5, p. 3 and IX, no. 2, p. 3.
The Progress of Metallography in 1899. *The Mineral Industry*, VIII, 702.
Biographical Sketch, F. Osmond, The Metallographist, III, 265.
The Metallographist, III, Edited.

*1901*

The Progress of Metallography in 1900. *The Mineral Industry*, IX.

The Microstructure of High Carbon Steel Quenched near its Melting Point. The Metallographist, IV, 252.

Biographical Sketch, Henri Le Chatelier. The Metallographist, IV, 265.

The Metallographist, IV, Edited.

*1902*

Biographical Sketch, John E. Stead. The Metallographist, V, 79.

Biographical Sketch, Dimitri Techernoff. The Metallographist, V, 175.

Structure and Finishing Temperatures of Steel Rails. *Int. Assoc. Test. Mat.*, June.

Biographical Sketch, George Charpy. The Metallographist, V, 255.

The Metallographist, V, Edited.

The Use of the Microscope in the Determination of the Properties of Steel. *Proc. Eng. Soc. W. Pa.*

*1903*

Biographical Sketch, Sir William Roberts-Austen. The Metallographist, VI, 1.

Note on the Influence of the Rate of Cooling on the Structure of Steel (with H. M. Howe). *Amer. Inst. Min. Eng.*, Feb.

The Casting of Pipeless Ingots by Sauveur Overflow Method (with Jasper Whiting). *Amer. Soc. Test. Mat.*

The Detection of the Finishing Temperature of Steel Rails by the Thermo-magnetic Selector (with Jasper Whiting). *Amer. Soc. Test. Mat.*, III.

The Metallographist, VI, Edited.

*1904*

Biographical Sketch, Henry Marion Howe. *Iron & Steel Mag.*, VII, 92.

Biographical Sketch, Robert Abbot Hadfield. *Iron & Steel Mag.*, VII, 209.

Biographical Sketch, Charles B. Dudley. *Iron & Steel Mag.*, VII, 259.

Biographical Sketch of A. Ledebur. *Iron & Steel Mag.*, VII, 535.

Iron and Steel Magazine, VII, Edited.

Biographical Sketch, Harry Huse Campbell. *Iron & Steel Mag.*, VIII, 82.

The Classification of Iron and Steel. *Amer. Soc. Test. Mat.*, June.

Biographical Sketch, Hans Freiherr v. Jüptner. *Iron & Steel Mag.*, VIII, 281.

Biographical Sketch, John August Brinell. *Iron & Steel Mag.*, VIII, 369.

Biographical Sketch, Maunsel White. *Iron & Steel Mag.*, VIII, 465.

Biographical Sketch, Bennet H. Brough. *Iron & Steel Mag.*, VIII, 569.

Iron and Steel Manufacturers; a volume to be published by the Van Slyck Publishing Co. (Written but not published).

*1905*

Biographical Sketch, W. E. Corey. *Iron & Steel Mag.*, IX, 55.
Biographical Sketch, Benjamin Talbot. *Iron & Steel Mag.*, IX, 175.
Biographical Sketch, K. Hermann Wedding. *Iron & Steel Mag.*, IX, 270.
Biographical Sketch, Samuel Thomas Wellman. *Iron & Steel Mag.*, IX, 364.
Biographical Sketch, David Baker. *Iron & Steel Mag.*, IX, 465.
Biographical Sketch, E. H. Saniter. *Iron & Steel Mag.*, IX, 564.
Metallography Applied to Foundry Work; a series of articles in *The Foundry,* beginning May.
*Iron & Steel Magazine,* IX, Edited.
Iron Manufacture, *Encyclopaedia Americana.*
Steel Manufacture, *Encyclopaedia Americana.*
Biographical Sketch, P.L.T. Héroult. *Iron & Steel Mag.*, X, 165.
Biographical Sketch, H. W. Raymond. *Iron & Steel Mag.*, X, 250.
Biographical Sketch, Sir Lowthian Bell. *Iron & Steel Mag.*, X. 354.
Biographical Sketch, Robert Forrester Mushet. *Iron & Steel Mag*, X. 443.
*Iron & Steel Magazine,* X, Edited.

*1906*

Biographical Sketch, Sir William Siemens. *Iron & Steel Mag.*, XI, 58.
Biographical Sketch, Leon Guillet. *Iron & Steel Mag.*, XI, 150.
Biographical Sketch, Alexander Lyman Holley. *Iron & Steel Mag.*, XI, 251.
Biographical Sketch, William Richard Jones. *Iron & Steel Mag.*, XI, 334.
Biographical Sketch, William Kelly. *Iron & Steel Mag.*, XI, 40.
Biographical Sketch, E. E. Ward. *Iron & Steel Mag.*, XI, 525.
*Iron & Steel Magazine,* XI, Edited.
Constitution of Iron Carbon Alloys. *Iron & Steel Inst.*, July.
On the Uniform Nomenclature of Iron and Steel (with H. M. Howe). *Int. Assoc. Test. Mat.*, Sept. 1.

*1907*

Metallography Applied to Foundry Works. *The Foundry,* Apr.
The Microstructure of Wrought Iron. *Electro. & Met. Ind.*, Apr.
Diagram of the Processes and Products of Iron and Steel Manufactured. *Iron Trade Review,* May 9, vol. XL, no. 19, 742-44.
The Metallography of Iron and Steel. *Encyclopaedia Americana,* VIII.

*1908*

A Graphical Representation of the Solidification of Eutectic Alloys. *Electro. & Met. Ind.*, Jan.

Note on the Structure of a Brittle Sheet of a Very Low Carbon Steel. *Electro. & Met. Ind*, July, 271.

Laboratory Experiments in Metallurgy. Part I, General Metallurgy. Part II, Metallurgy of Iron & Steel (with H. M. Boylston), pp. 73, 8 x 10½, 17 illustrations and 10 tables; cloth. Pub. by the authors Nov. 30, Cambridge, Mass.

*1909*

On the Uniform Nomenclature of Iron and Steel (with H. M. Howe). *Inter. Assoc. Test. Mat.*, Jan.

Notes on the Structure of a Very Pure Iron-Carbon Alloy. *Iron Trade Rev.*, Dec. 16, XLV, no. 25, 1053-54.

*1910*

A Magnetic Holder for the Microscopical Examination of Metals. *Iron Age*, June 23, 1511.

Apparatus for the Microscopical Examination of Metals. *Proc. Amer. Soc. Test. Mat.*, X, 318-350.

*1911*

The Antiquity of Iron. *Harvard Eng. Journ.*, 9: 223-227, Jan.

Metallography and Its Industrial Importance. Congress of Technology, Boston, Apr.

The Universal Metalloscope; a Perfected Microscope for the Examination of Metals. *Trans. Amer. Inst. Min. Eng.*

Practice Recommended for the Annealing of Steel (with H. M. Howe). *Amer. Soc. Test. Mat.*

*1912*

The Metallography of Iron and Steel. 430 pp., 366 ill. Cambridge, Mass.

Note on the Crystalline Growth of Ferrite Below Its Thermal Critical Range. *Int. Assoc. Test Mat.*

On the Uniform Nomenclature of Iron and Steel (with H. M. Howe). *Int. Assoc. Test. Mat.*, Sept.

The Nomenclature of the Microscopic Substances and Structures of Steel and Cast Iron (with H. M. Howe). *Int. Assoc. Test. Mat.*, Sept.

The Case Hardening of Special Steels (with G. A. Reinhardt). *Amer. Inst. Min. Eng.*, Sept.

The Structure, Composition, and Physical Properties of Steel. *Jour. Franklin Inst.*

*1913*

Biographical Notice, Floris Osmond. *Amer. Inst. Min. Eng.*, Feb.

Notes on Cast Iron. *Amer. Inst. Min. Eng.*, Feb.

The Practical Value of the Microscope in the Iron and Steel Industry. *Amer. Iron & Steel Inst.*, May.

The Allotropic Transformation of Iron. *Iron & Steel Inst.*, Sept.

Recommended Practice for the Heat Treatment of Case-Hardened Carbon-Steel Objects. *Amer. Soc. Test. Mat.*, July.

*1914*

Notes on Some Heating and Cooling Curves of Professor Carpenter's Electrolytic Iron. *Amer. Inst. Min. Eng.*, Feb.

Mild Steel and Its Treatment. *Jour. Franklin Inst.*, May.

Proposed Recommended Practice for the Annealing of Carbon-Steel Objects. *Amer. Soc. Test. Mat.*, July.

Manganese Steel and the Allotropic Theory. *Amer. Inst. Min. Eng*, Oct.

Germany and the European War. Boston, Nov.

Germany's Holy War.

*1915*

The Importance of Metallography to Foundrymen. New England Foundry Men Assoc., Nov. 10.

Metallography and the Hardening of Steel. *Inter. Eng. Cong.*, San Francisco, Sept.

*1916*

An Investigation dealing with the Occurrence of Aluminum Inclusions in Steel. *Met. & Chem. Eng.*, August 1.

*1918*

Materials and Treatments Recommended for Certain Parts of Airplane Motors. *Air Service*, A. E. F., Feb.

Heat Treatment of Some Aircraft Steels. *Air Service*, A. E. F., Feb.

Classification of Steels Used for the Construction of Airplane Motors. *Air Service*, A. E. F., Mar.

Relations Between Hardness and the Tenacity of Steel. *Air Service*, A. E. F., Apr.

Conversion Tables. *Air Service*, A. E. F., May.

*1919*

Some Remarks Concerning the Heat Treatment of Steel and Their Application to the Treatment of Steels used for Airplane Motors. *Jour. Franklin Inst.*, Aug.

Aircraft Steels. *Amer. Inst. Min. & Met. Eng.*, Sept.

*1920*

Improvements in Metallurgical Microscopes. *Faraday Soc.*

The Microscope and the Heat Treatment of Steel. *Amer. Iron & Steel Inst.*, May 28.

Steel Wizards, Past and Present. *Amer. Soc. Steel Treat.*, Sept.

*1921*

A Discussion of the Slip Interference Theory of Hardening. *Chem. & Met. Eng.*, Sept.

*1923*

Crystallization of Iron and Its Alloys *Trans. Amer. Soc. Steel Treat.*, July.

Making Wrought Iron in a New Way. *Sci Amer.*, Sept.

*1924*

Use of Sodium Picrate in Revealing Dendritic Segregations in Iron Alloys (with V. N. Krivobok). *Trans. Amer. Soc. Min. & Met. Eng*, Feb.

"What is Steel?" Henry Marion Howe Lecture. *Amer. Inst. Min. & Met. Eng*, Feb.

The Action of Heat on the Strength and Hardness of Iron and Steel. *Nat. Acad. Sci.* (Boston Meeting).

What is Steel? What is Iron? *Chem. & Met. Eng.*, XXX, no. 20.

*1925*

Le Fer Armco. *Revue de Metallurgie* (July).

Dendritic Segregation in Iron-Carbon Alloys (with V. N. Krivobok). *Iron & Steel Inst.*, Sept.

The Action of Heat on the Strength and Hardness of Iron and Steel (with D. C. Lee). *Iron & Steel Inst.*, Sept.

*1926*

The Durometer. An Instrument for Testing Hardness. *Amer. Soc. Steel Treat*, Sept.

The Current Theories of the Hardening of Steel Thirty Years Later. *Amer. Inst. Min. & Met. Eng*, Feb.

*1927*

The Widmanstättian Structure of Iron Alloys. Bicentenary number of *Amer. Phil. Soc.*

*1929*

The Gamma-Alpha Transformation in Pure Iron. *Amer. Inst. Min. & Met. Eng.*, Feb.

Austenite and Its Decomposition. *Amer. Soc. Steel Treat.*, Sept.

Steel at Elevated Temperature (Campbell Lecture). *Amer. Soc. Steel Treat.*, Sept.

Austenitic Steels—Fuels and Furnaces. Sept.

*1930*

The Influence of the Rate of Cooling on the Dendritic Structure and Microstructure of Some Hypo-Eutectoid Steel. *Amer. Inst. Min. & Met. Eng.*, Feb.

The Austenite-Pearlite Transformation and the Transition Constituents. *Amer. Inst. Min. & Met. Eng.*, Feb.

*1931*

L'Austenite et sa Décomposition. Metallurgical Congress, Liége.
The Austenite-Pearlite Transformation and the Transition Constituents. *Amer. Inst. Min. & Met. Eng.*, Apr.

*1932*

Early Experiments with X-Rays. *Metals and Alloys*, March.
Steel in the Light of the Precipitation Theory. *Metals and Alloys*, Aug. and Dec.

*1933*

A Method for Studying Strain Hardening Susceptibility and Aging after Cold Work Deformation (with John L. Burns). *Metals and Alloys*, Jan.
Notes on the Aging of Metals and Alloys. *Amer. Soc. Metals*, Sept.

*1934*

Malleable Castings (with H. L. Anthony). *Amer. Soc. Metals*, Oct.

*1935*

Metallurgical Dialogue *Amer. Soc. Metals.*
Le vieillissement des Aciers. Congrès International, des Mines, de la Metallurgie, et de la Géologie Appliquée, Paris, October.
A Simplified View of the Hardening of Steel and of the Transition Constituents. Imperial University, Sendai, Japan. Volume of Anniversary Theses.
The Metallography and Heat Treatment of Iron and Steel. Fourth Revised Edition, *University Press*, Cambridge, Mass.

*1937*

Metallurgical Reminiscences. Published for the Seeley W. Mudd Memorial Fund by the American Institute of Mining and Metallurgical Engineers.

*1938*

Wanted: International Committee on Nomenclature. *Metals and Alloys*, June.
Microscopical Constituents of Steel. *Metals and Alloys*, November.

*1939*

Why Torsion Tests? *Mech. Engr.*, LXI, 164.
Some things we do not know about Steel. *Metal Progress*, June.

D. W. Taylor

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—SEVENTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# DAVID WATSON TAYLOR

1864–1940

BY

WILLIAM HOVGAARD

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1941

# DAVID WATSON TAYLOR

## 1864–1940

BY WILLIAM HOVGAARD

David Watson Taylor was born on his father's farm in Louisa County, Virginia, on March 4, 1864, the son of Henry and Mary Minor (Watson) Taylor. After elementary education at home, he was sent to Randolph-Macon College, Ashland, Virginia, at the age of thirteen, the youngest boy in the college. Upon graduation in 1881, he was appointed to the United States Naval Academy and graduated as a cadet engineer in 1885 at the head of his class, with the highest scholastic record of any graduate of the Academy up to the present time. During his fourth year at the Academy, he was not only the ranking cadet, but a member of the football and baseball teams, president of the athletic association and chairman of the "hop" committee. After three months' service on the U. S. S. *Pensacola,* the flagship of the European Squadron, commanded by Captain George Dewey, he was selected by the Navy Department for assignment to study at the Royal Naval College in Greenwich, England. At that time there was no special course in this country for the design and construction of warships and naval machinery and for several years the Navy Department had sent young naval officers to study those subjects in England and France and later also in Germany. Taylor was ordered to England and entered the post-graduate course at Greenwich in 1885, specializing in marine engineering. He graduated from the Royal Naval College in 1888, receiving a first-class certificate, making the highest record of any English or foreign student at the College up to that time. While at Greenwich he was appointed Assistant Naval Constructor in 1886 because of his high standing at the College. In fact, at the annual examination of his first year at the College he was awarded a first prize in a class of 24 students.

Upon his return to the United States, Taylor was assigned to duty at Cramp's shipyard in Philadelphia.

In 1889 he was a member of the board of experts considering alleged defects in the battleship *Texas* building at Norfolk.

About the same time he assisted in preparing the designs of naval vessels for the consideration of the *Board of Naval Policy*. It was in those years that the upbuilding of the "New Navy" began, and Taylor took an active part in this work in several ways.

In 1891 he was promoted to the grade of Naval Constructor and from 1892 to 1894 he served as Construction Officer in the Navy Yard, Mare Island, California. In 1894 he was assigned to duty in the Bureau of Construction and Repair at Washington as principal assistant to the Chief Constructor. His connection with the designing and construction bureau of the Navy Department, thus commenced, continued throughout the remainder of his active career in the Navy. In 1898 he was ordered to Havana to arrange for and to fit the floating dry dock for towage to the United States. He was promoted to the rank of Commander in March 1899, to the rank of Captain in March 1901, and to the rank of Rear Admiral in 1917.

For about eight years, from 1914 to 1922, Admiral Taylor served as Chief Constructor and Chief of the Bureau of Construction and Repair. This term included the period of the World War. In 1917 he was appointed a member of the National Advisory Committee for Aeronautics, representing the Navy.

Admiral Taylor was retired at his own request, January 15, 1923, after more than forty-one years' service.

Following his retirement, Admiral Taylor served as Secretary of the National Advisory Committee for Aeronautics, 1923-1926, and was appointed Vice Chairman in 1927. He also served as Consultant for the Shipping Board.

In 1925 Admiral Taylor became a Director of Gibbs Brothers, Inc., Naval Architects and Marine Engineers, and later with the organization of Gibbs & Cox, Inc., in 1929, he became a Director of the new firm and also Vice-President.

Admiral Taylor married Imogene Maury Morris of Louisa County, Virginia, on October 26, 1892. They had four children: Dorothy Watson, May Coleman, David Watson and Imogene Morris.

In the spring of 1932, at a time of life when he might still have rendered further valuable service to the country, Admiral Taylor was stricken with paralysis and after this tragic event he was helplessly confined to chair and bed for the remaining eight years of his life. He spent his time largely at the Naval Hospital in Washington, always under the care of his wife. He died at the hospital on July 28, 1940.

### *Taylor as a Naval Architect and Scientist*

Even in the earliest years of his career, Taylor produced original work of practical and scientific value.

He critically investigated the various methods of "ship calculation" for the determination of displacement as well as the characteristics of buoyancy and stability and formulated a method of calculation which became the standard for the Navy.

In 1893 he wrote his first book entitled: *Resistance of Ships and Screw Propulsion*, a subject which was to become his life's principal work. This book formed the foundation for his later more complete and classical volume to be described below.

In 1894 Taylor read a paper entitled: "Ship-shaped Stream Forms," before the British *Institution of Naval Architects*, in which was revealed his high analytical ability and capacity for original mathematical research. This paper was awarded the gold medal of the Institution in 1895, the first time this honor was bestowed on an American.

Taylor brought to the attention of the naval authorities the great handicap under which the naval designers of the United States labored through lack of experimental facilities, notably a model basin for experimentation with small ship models, such as possessed at that time by several foreign governments and private establishments. His persistent advocacy and convincing arguments for the need of such facilities led to the appropriation of funds for the establishment of the Experimental Model Basin at the Washington Navy Yard. The details of the design of the Model Basin and its actual construction were placed under the immediate supervision of Taylor and the basin was completed and ready for operation by 1899. He then began an extensive and systematic series of experiments and investigations

on the subject of resistance to the propulsion of ships and on the action of propellers, which continued under his immediate direction up to the time of his appointment as Chief of the Bureau of Construction and Repair in 1914. The results of these systematic investigations were scientifically analyzed and tabulated, and from time to time conclusions deducible therefrom, with supporting data, were published in various papers, mostly in the *Transactions of the Society of Naval Architects and Marine Engineers,* of which he was one of the founders.

In 1910, the extensive research work performed by Taylor up to that time, in connection with the model basin, was published in his great work: *"The Speed and Power of Ships,"* which has become internationally known as the standard book on this subject. In the preface Taylor sums up the purpose of this book in the following words:

"The intention of this work is to treat in a consistent and connected manner, for the use of students, the theory of resistance and propulsion of vessels and to give methods, rules and formulae which may be applied in practice by those who have to deal with such matters. The contents are based largely upon model experiments, such as were initiated in England nearly half a century ago by Mr. William Froude and are now generally recognized as our most effective means of investigation in the field of resistance and propulsion. At the same time care has been taken to point out the limitations of the model experiment method and the regions where it ceases to be a reliable guide."

After an introductory chapter on hydrodynamics, pertinent to this subject, the book deals comprehensively with the problem of resistance to driving a ship through water, in all its aspects, with special regard to the use of small models. The results of the vast experimental work are expressed in a great number of diagrams, giving curves which represent the resistance of a series of models, derived from a parent form by variation of the principal characteristics such as beam-draught ratio, speed-length ratio, coefficients of fineness, etc.

The third chapter is devoted to the difficult subject of propulsion, which is here treated in a most complete and masterly manner. It comprises the general theory of propeller action, the results of extensive series of experiments with small models,

presented in numerous diagrams by curves, various special problems such as that of cavitation, and finally a full discussion of the strength and design of propeller blades.

The last chapters deal with ship trials and their analysis, and with the important practical problem of powering of ships, that is, the calculation of the engine power required to drive a given ship at a certain speed.

Altogether the book is an outstanding classic in engineering literature. Taylor had the rare advantage of a brilliant mind and a natural talent for expressing himself in concise scientific language. He was never satisfied until he had reached perfection in exposition and he avoided always the pitfall of stating opinions that were not completely buttressed by facts. His talent for experimental work found the best possible opportunity for development and achievement, due to the fact that he had at his disposal and under his independent direction a well equipped experimental plant, shaped according to his own ideas and provided with an exceptionally able staff of his own selection and trained by himself. His master mind used this tool to full efficiency.

The Navy Department allowed Taylor to hold his position as scientific expert and head of the Experimental Model Basin in Washington continuously for about twenty years. This is contrary to the ordinary routine according to which officers do not hold the same commission or office for more than four years. Thus Taylor was given the opportunity of continuous and consistent study and research, and the outcome was a work of rare excellence and value.

In 1933 a second revised edition of his book was published, following closely the same principles in mode of presentation, but containing much new material, largely based on experimental data from the model basin, accumulated since the publication of the first edition in 1910. The new edition was prepared with the assistance of Lieutenant Commander A. S. Pitre (CC), U. S. Navy, the Admiral's capacity for work being at that time impaired by his illness. The book has placed ship designers of all countries under a great and lasting obligation to Admiral Taylor.

In 1909 Taylor published a paper on "Some Model Experiments on Suction of Vessels," read before the Society of Naval Architects and Marine Engineers in New York, explaining the "suction" which tends to draw ships together when they pass close to one another. Not long after, a collision occurred between the British cruiser *Hawke* and the White Star liner *Olympic*. In the ensuing trial the British Admiralty claimed that the collision was due to "suction" and in 1911 Taylor's services as technical expert were requested by the Admiralty and were loaned by the United States Government. The decision, which was strongly influenced by Taylor's testimony, was in favor of the Admiralty's contention.

The work at the Model Basin under Taylor's guidance extended outside the field of resistance and propulsion of ships and came to comprise several other problems in engineering.

To the writer's knowledge, one of the earliest and most complete sets of experiments on the artificial ventilation of ships was that made by Taylor at the Experimental Model Basin. His experiments were conducted through a number of years and led to a rational scientific mode of design of ventilating systems, now adopted in the United States naval vessels.

In 1901 he published a paper on the balancing of reciprocating marine engines, giving the most complete analysis of the problem up to that time. An analysis and experiments were made on the problem of gyroscopic control of the rolling of vessels for the late Dr. Elmer Sperry, which proved to be most useful in the development of the Sperry control apparatus.

Taylor was appointed Chief Constructor with the rank of Rear Admiral in 1914 and served in that capacity during the World War and until 1922. He was responsible for the design of an unprecedented number of vessels; actually more than 1,000 vessels, large and small, with a total displacement of about 1,200,000 tons, were built under his supervision, while in addition half a million tons of vessels were designed and begun, but discontinued or scrapped after the Washington Naval Conference of 1922.

*Achievements in Aeronautics*

The following is quoted from the "commemorative appreciation" by Dr. W. F. Durand on the occasion of the award of the John Fritz medal to Admiral Taylor in 1930:

"Admiral Taylor has made notable contributions in the field of Aeronautics chiefly through two connections with public affairs: first, as Chief Naval Constructor and second, as member of the National Advisory Committee for Aeronautics.

"In the early developments in the Navy, with reference to aircraft both heavier than air and lighter than air, the responsibility for design and for supervision of construction were placed in the office of the Chief of Naval Construction, the same for aircraft as for water craft. Admiral Taylor, as Chief Naval Constructor bore from 1915 until 1921, when the Bureau of Aeronautics was formed, the entire responsibility for the design and construction of Naval Aircraft, which were carried brilliantly forward under his direction. Perhaps the most notable achievement was the development of the NC type of flying boat, initiated by Admiral Taylor with the idea of having Naval seaplanes of the patrol type, capable of flying across the Atlantic and thus of insuring their presence in European waters if German submarine warfare should prevent their shipment on surface vessels.

"In 1917, Admiral Taylor was appointed a member of the National Advisory Committee for Aeronautics, representing the Navy. Upon retirement as Chief Constructor in 1922, he was reappointed from civil life, in appreciation of his distinguished attainments. He served as Secretary, 1923-1926, as Vice-Chairman, 1927-1930, and as chairman of the committees on Aerodynamics and on Aeronautical Inventions, since 1927.

"Of the equipment for aeronautic research at the Committee's laboratory at Langley Field, for which Admiral Taylor has been largely responsible, the variable density wind tunnel set a new mark in the field of experimental research on reduced scale models; the full scale propeller research tunnel; the full scale wind tunnel, and the seaplane towing channel, are unique in size and in the boldness and character of their design. They are quite unapproached elsewhere in the world.

"Through the pioneer work of the Bureau of Construction and Repair under his direction, and through his long and effective service as member and officer of the National Advisory Committee for Aeronautics, Admiral Taylor has made a deep and lasting imprint on the development of Aeronautics in the United States."

It may be added that it was largely due to Admiral Taylor's vision that the Bureau of Aeronautics was established. He realized the need for an independent bureau in the Navy Department to handle the great expansion in Navy aviation which he so clearly foresaw. He used his great personal influence in the Navy Department and in committees in Congress to obtain the necessary legislation. When the new bureau was set up he assisted it by turning over to its control a great part of the commissioned and civil personnel which formed its original staff.

It is of interest to note that the flying boat NC-4 was the first heavier-than-air craft to cross the Atlantic.

*Character and Personality*

In order to throw light on the character and personality of Admiral Taylor, the following tributes from some of his colleagues and friends are here given.

Rear Admiral George H. Rock, one of his contemporaries in the Construction Corps, writes as follows:

"I never knew any one who I thought had such a fine mind, was so broad as well as practical in all matters, had such clear foresight and, withal, was so gentle and lovable at all times. He had, also, that truly rare gift of being able to answer a question without making the inquirer feel that he should have known the answer. Always plain spoken, he never gave offense, even to supersensitive or to poorly informed persons, because of his natural manner and his well-chosen words. His character, his fine instincts, his unobtrusiveness and his intuitive knowledge of persons and of affairs, were so exceptional as to place him above others without causing any jealousy or ill feeling—only respect and admiration. My feelings are the result of some forty years of intimate and affectionate friendship."

Captain Lewis B. McBride (CC) USN. (Ret.), writes:

"It was my privilege to serve under Admiral Taylor during several periods and to enjoy his friendship for thirty years. Others have paid tribute to his technical and scientific accomplishments. To me these were always overshadowed by his human qualities; his wisdom, common sense, humor and intuitive understanding of other human beings and their problems. It was these qualities that led so many men of high standing in political and business life to seek his advice and to be influenced

by his judgment. He was a philosopher as well as a man of science and a man of action; a man who would have attained distinction in any field of human endeavor which he had chosen to enter."

Mr. William Francis Gibbs, Vice-President of Gibbs & Cox, Incorporated, writes:

"My brother and I met Admiral Taylor in about 1914 while he was Chief Constructor of the Navy, and thereafter we consulted with him on problems of propulsion. We came to have a very high regard for his foresight and calm judgment and his almost intuitive approach to propulsion problems.

* * *

"With his retirement in 1923 the thought occurred to us he might be willing to join with us in a consulting capacity. Considering Admiral Taylor's great reputation and standing and our relative inexperience and the difficult periods through which we were passing, it was with diffidence that we suggested the possible alliance. Admiral Taylor accepted this suggestion with alacrity and we were very proud of the fact that such an outstanding figure was willing to join with us.

"In joining our firm he explained that one of his reasons was that we were trying to accomplish a forward looking advance in the art. * * *

"His advice was invaluable, not only on technical matters, but particularly on the policy of the firm and his insistence on a forward looking and high quality of design was an inspiration to us all.

"Admiral Taylor, during his connection with our firm, and up to the time of his illness in April 1932, had an intimate connection with all of our work, and his efforts were particularly outstanding in the design of the four Grace Line ships, the Santa Rosa, Santa Paula, Santa Lucia and Santa Elena. These ships were outstanding in economy and very high propulsive efficiency, and their success was in large part due to Admiral Taylor's assistance.

"During our years of association and after his illness when we all saw him from time to time at the hospital, he had endeared himself to all of us, and my brother and I counted on him as our best friend and wisest counsel. His courtesy, consideration, wisdom and vast technical skill and intuition commanded our deepest admiration.

"We have always been proud that Admiral Taylor associated himself with our firm. He gave us confidence that the prin-

ciples for which we were contending were right and worthwhile, and we like to think that the progress which we have made was a matter of satisfaction to him and was the result of the wisdom of his advice and his helpful counsel."

Rear Admiral E. S. Land (CC), U.S.N. (Ret.), Chairman of the United States Maritime Commission, writes:

"David W. Taylor was my 'father confessor' from 1913 to the time of his death—a period of twenty-seven years.

"No important step in my career was taken without obtaining his advice.

"I always looked upon him not only as the outstanding naval architect and marine engineer of the world but also as the wisest man of my acquaintance.

"In my sixty-odd years of existence no other man had as much to do with my professional career as Admiral Taylor.

"His sense of humor was so keen, his interests were so varied, his knowledge so great, and his character so splendid, that it was a genuine pleasure to consult him on any subject from football to the square root of minus one!

"During his protracted illness it was always an inspiration to me to visit him and one left him with renewed determination to solve the problem at hand.

"He was a man among men. 'All the world could stand up and say: "This is a man."'

"I can only add that he had my deep affection and great esteem."

Professor Henry H. W. Keith, Head of the Department of Naval Architecture and Marine Engineering, Massachusetts Institute of Technology, writes:

"I worked for Admiral Taylor as a ship draftsman at the Model Basin in the Washington Navy Yard from 1905 to 1910, starting in immediately after graduation from M. I. T. At that time the Model Basin had been in operation only a short time and most of the work was necessarily of pioneer character. I have always felt that I was particularly fortunate in being there during those early years as, in addition to the routine work of testing models of hulls and propellers, a great deal of original research was carried on under Admiral Taylor's supervision. While I was at the Basin, his book 'The Speed and Power of Ships' was written and published, his work on the mathematical lines of ships was developed, and his early

experiments in connection with the ventilation of ships and the application of the gyroscope in rolling were undertaken.

"Although I had but a small part in these projects, I was kept extremely busy in trying to keep up with the work, and I well remember the extra studying I had to do in order to understand what it was all about. Admiral Taylor always took a personal interest in whatever work was in hand, and in my case I shall always look back with extreme gratitude for the time he spent with me at my own drafting table. His comments were always very much to the point, and the brief contacts I had with him will always be a treasured memory."

Commander A. S. Pitre of the Construction Corps, who had the opportunity to work with the Admiral during his final illness, writes as follows:

"I knew the Admiral only after he had been stricken in the spring of 1932. After regaining some measure of relief, he requested that I complete the revision, that he had undertaken, of his 'Speed and Power.' I was in no wise fitted for this important task, but despite my protest and with the renewal of his request, I was persuaded to undertake this work.

"His condition during the early stages of his illness did not permit of any extended technical discussions. I was requested to confine my remarks to 'restful' subjects. Later, with his remarkable recovery (I refer to his mental faculties), we did engage in some technical discussions especially concerning problems of propulsion that continually challenged his interest. I found him always eager to hear of our work and progress in the Model Basin (where I was attached at the time).

"The predominating characteristics that excited my admiration were his high courage and genial disposition during so many days that must have been a real trial to all his hopes and plans. I never found him cross, unwilling to talk, nor impatient with me in my own poor efforts to afford him some measure of social as well as professional companionship. When he found that I too liked detective stories, we enjoyed many a moment. His interest in this 'terrible stuff' (this is Mrs. Taylor speaking) ran entirely to the fiction side.

"I was detached from Washington in October 1935. Up to that moment, I never once saw the Admiral but what his hopes were high that some day he would walk again. He continually looked forward to the summers when he was permitted to return to his home at Waldrop, Virginia. At this time he again

indulged in his hobbies—farming and the raising of bees. When he returned to the hospital in the fall, he immediately started anticipating his return trip to the farm in the following summer. These personal observations may not sum to very much but to my unpracticed eye, they really are a great monument to his courage and to the serenity of his common sense philosophy."

There is one field of work which commanded Admiral Taylor's continued interest over almost forty years which has not, apparently, received mention in any other obituary or memoir; that is, his interest in insurance. The Navy Mutual Aid Association was founded many years ago as a form of mutual assessment insurance for officers of the service. Captain John R. Hornberger (SC) USN., (Ret.), the present secretary of the Association, gives the following memorandum on Admiral Taylor's service to the Association:

"Rear Admiral D. W. Taylor was elected a member of the Board of Directors of the Navy Mutual Aid Association on 4 January 1898. He served continuously as a member of this Board until his death, 28 July 1940. He held the office of Vice President from January, 1910, until January, 1923.

"During his long service as a member of the Board of Directors, Admiral Taylor contributed much to the success of the Association. He conducted such actuarial studies as were made during his active period of membership, and was responsible for the preparation of the assessment ratios and rates established in 1900. He prepared a pamphlet on Navy Mutual Aid protection and on the general subject of insurance in 1914, and a similar publication in 1930, commemorating the fiftieth anniversary of the Association.

"Although unable to attend the meetings of the Board of Directors during his last years, Admiral Taylor retained a lively interest in the Association and his advice and suggestions were most helpful to me in making the studies which led to the change to the level premium basis on 1 January 1939."

In recording the personal contacts which the writer of this memoir had with Admiral Taylor, the personal pronoun will be used for the sake of briefness and convenience.

It was my privilege to become intimately acquainted with Admiral Taylor and to form a friendship with him while we were still young. This happened at the time when he studied

at the Royal Naval College in Greenwich, where our terms of study overlapped by one academic year, 1885-6, this being his first and my last year.

At the end of April in 1886, during our Easter vacation, Taylor and I made a trip to Paris on a tricycle. As Taylor did not ride a bicycle, we chose a tricycle of the "sociable" type, where we sat abreast of each other. We took the boat from Newhaven to Dieppe and went through Rouen, Alençon, Le Mans, Nogent-le-Rotrou, Chartres to Versailles, from where we took the train to Paris. France looked beautiful in the warm and sunny spring weather and people were everywhere very friendly. At that time bicycles were little known in France and our novel machine, as well as our cyclist dress, made quite a sensation: "Ah, voilà la petite voiture!" Sometimes people would stop, laugh at us and shake their heads exclaiming: "Voilà les Anglais!" When, driving through a village, we took a child up in front of our machine, people were delighted.

I saw Taylor again on visits to London in 1887 and 1888, and it was always a wonder to me how easily he carried the load of the course, which on the side of mathematics was very heavy indeed. Yet, he obtained a first-class certificate and passed his final examination with the highest record ever attained at the Royal Naval College up to his time.

On one of my visits to London in 1887, together with the Danish Chief Constructor, Commodore K. Nielsen, Taylor took dinner with us. The Commodore, who was known as a keen observer of men, was much impressed by Taylor and remarked to me afterwards: "That young man is a genius!"

At the beginning of 1901, I was ordered by the Danish Government on a voyage of study to the United States for the purpose of investigating the problem of submarine boats, which had just then, after many years of experimentation, been solved by John P. Holland. On that occasion I again had the pleasure to meet Taylor, who was most hospitable and helpful to me and I had an opportunity to see the newly established Model Basin. When I left Washington I said to him: "Well, goodbye,

I suppose we shall never meet again." "Oh," he said, "don't be too sure of that; somehow, when people once find their way to this country, they usually come back again." I did not attach any importance to this remark, but a few months later, in May, I received an invitation from Massachusetts Institute of Technology to take charge of the new Course in Naval Construction, which it was planned to establish for the training of young American naval officers in that subject. As I learned afterwards, it was due to Taylor's suggestion and his influence with the Chief Constructor, Rear Admiral Francis T. Bowles, that I had the honor to be selected for this task.

In all my early years in this country I met the greatest hospitality and friendship in Taylor's home in the Washington Navy Yard. From the Model Basin, Taylor supplied me with much information and rendered assistance which was of the greatest value in my work of instruction. On more than one occasion, special experiments were carried out in the tank in order to assist me in my research work. Taylor's books and papers were in constant use in my course and were of the greatest assistance in the instruction.

On one occasion I tried to assist Taylor in his hobby of farming. He asked me to get for him some Danish walnuts, which he thought would be perhaps more hardy than the American walnuts and better capable of standing the climate of Virginia, but it appears they were not entirely successful.

### *Various Activities and Honors*

Admiral Taylor was a member of the *Society of Naval Architects and Marine Engineers* from its foundation in 1893, and contributed to it twenty scientific papers, many of them of great importance for the science of naval architecture and naval construction. He was President of the Society for three years, from 1925 to 1927, and in 1936 the Society established in his honor the David W. Taylor Medal, the first award of which was made to Rear Admiral Taylor for "notable achievement in naval architecture and marine engineering."

Referring to his service as Chief Constructor during the World War, he was awarded the Distinguished Service Medal by Congress for "exceptionally meritorious service in a duty of great responsibility." For similar service he was made a Commander of the Legion of Honor by the French Government.

It has been already mentioned that in 1895 Admiral Taylor was awarded the Gold Medal of the British *Institution of Naval Architects* for his paper: "On Ship-shaped Stream Forms." In 1901, he was awarded a prize by the Society of *Naval Architects and Marine Engineers.* In 1907 he was awarded the Gold Medal of the *Franklin Institute,* Philadelphia. In 1931 he was awarded the Shipbuilding Gold Medal of the *North East Coast Institution of Engineers and Shipbuilders of England,* of which he had been an Honorary Fellow since 1925.

He was awarded the honorary degree of Doctor of Engineering by *Stevens Institute of Technology,* Hoboken, N. J., in 1907; the honorary degree of Doctor of Science by *George Washington University,* Washington, D. C., in 1915; the honorary degree of Doctor of Laws by *Randolph-Macon College,* Ashland, Va., in 1922, and the same degree by the *University of Glasgow,* Scotland, in 1924. He was nominated Honorary Vice-President of the *Institution of Naval Architects* in London, 1931. He was awarded the John Fritz Gold Medal for 1931, by the *American Society of Civil Engineers,* the *American Institute of Mining and Metallurgical Engineers,* the *American Society of Mechanical Engineers* and the *American Institute of Electrical Engineers,* for "outstanding achievement in marine architecture, for revolutionary results of persistent research in hull design, for improvements in many types of warships and for distinguished service as Chief Constructor of the United States Navy during the World War."

Admiral Taylor was elected a member of the *National Academy of Sciences* in 1918.

On October 5, 1937, the Secretary of the Navy issued General Order No. 100 reading as follows: "The Naval Experimental Model Basin, Carderock (P. O. Cabin John), Maryland, is hereby established and will be known as *'The David W.*

*Taylor Model Basin'.*" On November 4, 1939, the new model basin was formally dedicated in the presence of Rear Admiral Taylor himself as well as of all Navy Department employees in Washington, both active and retired, who had served with Rear Admiral Taylor at the Experimental Model Basin and at the Bureau of Construction and Repair. On behalf of the members of the Construction Corps, Rear Admiral and Mrs. Taylor were presented with an etching of the Admiral executed by Mr. Harry Moskowitz of Philadelphia. A reproduction of this etching presented by Mrs. Taylor is incorporated in this memoir.

Admiral Taylor was a member of the Phi Beta Kappa, the Phi Kappa Psi, and the Army and Navy Club of Washington.

## BIBLIOGRAPHY

### BOOKS

*1893*

Resistance of Ships and Screw Propulsion. Macmillan. Reprinted 1907.

*1910*

The Speed and Power of Ships. Two volumes. First Edition. John Wiley & Sons, New York.

*1933*

The Speed and Power of Ships. One volume. Second Edition. Ransdell Incorporated, Washington, D. C. Printed by United States Shipping Board.

### PAPERS

*Transactions of the Society of Naval Architects and Marine Engineers—New York*

The Wetted Surface of Ships. Vol. 1, 1893.
Methods and Forms for Certain Ship Calculations. Vol. 3, 1895.
The United States Experimental Model Basin. Vol. 8, 1900.
The Theoretical and Practical Methods of Balancing Marine Engines. Vol. 9, 1901. Awarded a prize.
On Ships' Forms Derived by Formulae. Vol. 11, 1903.
Some Recent Experiments at the U. S. Model Basin. Vol. 12, 1904.
Experiments with Ventilating Fans and Pipes. Vol. 13, 1905.
Model Basin Gleanings. Vol. 14, 1906.
An Experimental Investigation of Stream Lines around Ships' Models. Vol. 15, 1907.
The Influence of Midship-section Shape upon the Resistance of Ships. Vol. 16, 1908.
Some Model Experiments on Suction of Vessels. Vol. 17, 1909.
The Effect of Parallel Middle Body upon Resistance. Vol. 17, 1909.
Some Model Basin Investigations of the Influence of Form of Ships upon their Resistance. Vol. 19, 1911.
Relative Resistances of some Models with Block Coefficient Constant and other Coefficients Varied. Vol. 21, 1913.
Some Experiments with Models having Radical Variations of After Sections. Vol. 22, 1914.
Some Experiments on Propeller Position and Propulsive Efficiency. Vol. 30, 1922.
Propeller Design Based upon Model Experiments. Vol. 31, 1923.
Comparison of Model Propeller Experiments in Three Nations. Vol. 32, 1924.

President's Address. Vol. 33, 1925.
President's Address. Vol. 34, 1926.
President's Address. Vol. 35, 1927.
Model Results of a Four-bladed Propeller Series. Vol. 37, 1929.
Tests of Modern Propellers of Various Blade Sections. Vol. 38, 1930.

*Transactions of the Institution of Naval Architects—London*

Ship-Shaped Stream Forms. Vol. 35, 1894 Awarded Gold Medal, 1895.
Solid Stream Forms and the Depth of Water Necessary to Avoid Abnormal Resistance of Ships. Vol 36, 1895.
Wake Propeller Coefficients. Vol. 67, 1925.

*Proceedings of the United States Naval Institute*

Architecture Navale (Review). Vol. 16, 1890, No. 55, p. 600.
On a Method for Calculating the Stability of Ships. Vol. 17, 1891, No. 58, p. 157.
On Determining the Inclinations of Non-Algebraic Curves from their Ordinates. Vol. 17, 1891, No. 59, p. 533.
Our New Battleships and Armored Cruisers. Vol. 27, 1900, No. 96, p. 593.
On Proposed New Type of Battleship. Vol. 28, 1902, No. 102, p. 272.
Present Status of Protected Cruiser Type. Vol. 30, 1904, No. 109, p. 145.
A Handicap on U. S. Battleships. Vol. 30, 1904, No. 111, p. 501.
Comment on the Size of Battleships as a Function of their Speed. Vol. 33, 1907, No. 121, p. 133.
New Method for Determining the Final Diameter of a Ship. Vol. 36, 1910, No. 134, p. 501.
Influence of Trim upon Resistance of Ships. Vol. 36, 1910, No. 135, p. 665.
On *Hawke-Olympic* Collision. (Transcript of Official Judgment.) Vol. 38, 1912, No. 141, p. 283.
On Life Insurance. Vol. 39, 1913, No. 145, p. 349.
On Naval Aviation and a United Air Service. Vol. 47, 1921, No. 218, p. 566.
On the General Board. Vol. 48, 1922, No. 231, p. 792.
Some Reflections upon Commissioned Naval Personnel Problems. Vol. 50, 1924, No. 261, p. 1771.
Book Review: Interaction between Vessels, by R. B. Bodilly. Vol. 51, 1925, No. 266, p. 692.
Book Review: The Theory and Practice of Steering, by G. F. Leechman. Vol. 53, 1927, No. 291, p. 617.

*Miscellaneous Papers and Articles*

Speed Trials. *Journal of American Society of Naval Engineers.* Vol. 4, 1892, p. 587.

Simple Explanation of Model Basin Methods. *Scientific American.* Vol. 97, 1907, p. 418.

The Science of Naval Architecture. *Journal, Franklin Institute.* Vol. 184, 1907, pp. 1-13. Awarded the Gold Medal.

Lesson from the Titanic Disaster. *Popular Mechanics,* 1912.

Maximum Parcel. *Scientific American.* Vol. 109, 1913, p. 51.

Calculations for Ship's Forms and the Light Thrown by Model Experiments upon Resistance, Propulsion and Rolling of Ships. *International Engineering Congress,* 1915, San Francisco. (Naval Architecture and Marine Engineering), pp. 1-67.

Calculations for Ships' Forms. *Scientific American,* Supplement. Vol. 81, 1916, pp. 182-3.

Science of Naval Architecture. *Scientific American,* Supplement. Vol. 83, 1917, pp. 386-7.

Some Aspects of the Comparison of Model and Full-Scale Tests. *Royal Aeronautical Society of Great Britain,* 1925.

The Cost of Navy Mutual Aid Insurance. Pamphlet, Navy Mutual Aid Association, U. S. Navy Department, 1914.

Present Status of the Navy Mutual Aid Association. Pamphlet, Navy Mutual Aid Association, U. S. Navy Department, 1927.

Propeller Design Developments. *World Engineering Congress in Japan,* 1929.

Life Insurance. The Navy Mutual Aid after Fifty Years. Pamphlet, Navy Mutual Aid Association, U. S. Navy Department, 1930.

Variation of Efficiency of Propulsion with Variation of Propeller Diameter and Revolutions. *North East Coast Institution of Engineers and Shipbuilders of England.* Vol. 47, 1931, p. 317. Awarded the Gold Medal.

F. L. Ransome

NATIONAL ACADEMY OF SCIENCES

OF THE UNITED STATES OF AMERICA

BIOGRAPHICAL MEMOIRS

VOLUME XXII—EIGHTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# FREDERICK LESLIE RANSOME

1868–1935

BY

EDSON S. BASTIN

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1941

# FREDERICK LESLIE RANSOME

## 1868–1935

BY EDSON S. BASTIN

Frederick Leslie Ransome was born in Greenwich, England, December 2, 1868, and came of Quaker stock. When he was only two years old his family emigrated to San Francisco, arriving there in 1870 when the city was in a period of rapid building and commercial development. His father, Ernest Leslie Ransome, founded there the Ransome Concrete Machinery Company and became a pioneer in American concrete construction, building the first concrete building and the first concrete bridge in America. He died in 1917. Of him Dr. Ransome wrote "From my father was probably inherited or learned a fondness for mechanical work, some recognition of the importance of systematic and conscientious industry, a realization of the importance of truth and personal integrity, and a sense of impartial justice." Ransome's mother, Mary Jane Dawson Ransome, was the daughter of a farmer in Suffolk, England. Of her he wrote "whatever love I have for good books, music, and art comes chiefly from my mother."

Ransome's elementary and secondary education was obtained in the California schools and his higher education at the University of California, from which he graduated in 1893. At the time he entered the University there was little to awaken a young man's interest in geology except the personality of Joseph Le Conte and almost no attempt was made to utilize the great natural advantages of the region for schooling in field geology. In 1890, however, Andrew C. Lawson came to Berkeley fresh from his doctoral work at Johns Hopkins as professor of mineralogy and geology. In the words of one of Ransome's fellow students, Lawson "was like a spark in dry tinder to us older students" and we "took fire at the first suggestion of field work."

In the summer of 1892 Lawson began geologic field work on the San Francisco sheet with Charles Palache as his assistant and the next summer Ransome began geologic surveys north

of the Golden Gate in Marin County. This was virtually the first detailed geologic mapping done in California. In 1894, when Charles Palache went abroad for study, Ransome succeeded him as Lawson's assistant. Of their closely related work at this time Palache writes:[1]

"We were both interested in the glaucophane schists which were well developed in Marin County and one of Ransome's earliest papers (1894) was a fine one on the contact metamorphic origin of the schist on Angel Island, disproving the older idea that they were of regional metamorphic origin. We collected together on many trips and among the specimens we brought in on one occasion were crystals of a mineral neither of us were sufficiently good mineralogists to recognize as a new species. Two years later, and simultaneously, he in Berkeley and I in Munich, studied it, found it new and both picked for it the same name—lawsonite."

Ransome completed his work for his doctorate at Berkeley in 1896 and shortly thereafter went to Harvard University where for a year he served as assistant in mineralogy and petrography, working in close association with his friend and former classmate Palache, who writes[2] as follows in regard to those days in Cambridge and Boston:

"Ransome lived that winter, for reasons of economy, in a dreary brick cell on the fourth floor of the Museum where I had spent the previous winter. However he had the run of my more comfortable quarters in a nearby dormitory and we spent much time together there and at our meals at a club table in the College Commons in Memorial Hall. We shared a ticket to the Boston Symphony concerts in Boston, using it alternately. And many evenings were spent in my room with a group of whom I remember chiefly Irving Babbit, Charles Cestre, Charles Bakewell, and Tom Jaggar. Daly was abroad that winter and there were no other young men on the Harvard geological staff. The three men first named all made names for themselves in philosophy or letters and our talks were largely of literary matters. Kipling was just becoming the style and I remember our enthusiastic enjoyment of some of his poetry. Leslie and I went together to a few pleasant Cambridge homes and took many walks in the outlying New England country.

[1] Personal letter, January 31, 1941.
[2] Personal letter.

He had never been in the east before and found it much to his liking. He haunted the Boston book shops and art galleries."

While still at Berkeley, Ransome had been appointed a field assistant with the United States Geological Survey and the next year, having passed the Civil Service examination, he was appointed assistant geologist and invited to devote his full time to Survey work and to take up his residence in Washington, D. C. Thus was begun his long and fruitful career with the United States Geological Survey which was to bring him worldwide recognition.

His first Survey assignment took him back to his well-loved state of California and launched him at once, in collaboration with H. W. Turner, upon a study of the principal gold belt of California—the Mother Lode—one of the greatest gold producing regions of the world. The economic aspects of these studies culminated in 1900 with the publication of the Mother Lode Folio.

Soon after assuming his duties in Washington, Ransome became acquainted with Miss Amy Cordova Rock, then a student of geology and assistant to J. S. Diller of the Geological Survey. Miss Rock was the daughter of Miles Rock, astronomer and civil engineer. Their friendship and community of interests led to still closer bonds culminating in their marriage in 1900. A son and three daughters blessed this very happy union.

From its auspicious beginning on the Mother Lode, Ransome's field of activity shifted in succession to the San Juan region of southwestern Colorado, and in 1902 to Globe and Bisbee, Arizona. In 1904 he began, in collaboration with Waldemar Lindgren, the study of the Cripple Creek District in Colorado which, because of the richness of the deposits, their unusual mode of occurrence, and the skill with which they were studied and described, has become one of the classics of American economic geology. Ransome's next important study, begun in 1905 and published in 1908, was of the geology of the great lead producing district of the western United States, the Coeur d'Alene in Idaho, a district also characterized by features of

unusual interest. There followed a succession of valuable reports on the Goldfield and Yerington and Humboldt County ore deposits in Nevada (1909), on Breckenridge, Colorado (1911), and on Superior, Ray, Miami and Oatman, Arizona (1914-1923).

In the preparation of the Breckenridge report the writer served as Ransome's assistant and had an opportunity to observe and profit by his methods of field work. His work went forward with an unspectacular smoothness and effectiveness as a result of steady effort systematically applied. No time was wasted; maps and notes were meticulously kept up day by day. His assistants learned by the force of his example and no better schooling could have been had.

Ransome began his work with the United States Geological Survey under the administrative supervision and inspiring guidance of that great pioneer in applied geology in America, Samuel F. Emmons. With the death of Emmons in 1911, Waldemar Lindgren became his chief and the relations between Ransome and Lindgren were characterized by mutual confidence and respect. With Lindgren's promotion to Chief Geologist in 1912, Ransome succeeded him in charge of the metalliferous work and held that position until he left Washington in 1923.

Ransome's great contribution to American geology lay in his exceptionally orderly and lucid descriptions of so many of the important mining camps of the United States. He seldom went beyond the clear implications of his facts into the realm of speculation. He laid, however, a large and secure foundation of factual material absolutely essential for the development of any enduring concepts of the processes of ore formation. As Lindgren has said, "he built in his own chosen field of science, solid structures not easily destroyed, which stand the test of time." He was a skilled rhetorician in his own writing and critical of poor writing on the part of his colleagues whose manuscripts passed across his desk for criticism. One of his marked characteristics as an administrator was the promptness with which he acted upon all manuscripts that came to him from members of his section.

From time to time there came from Ransome's pen geologic

writings briefer than his regional monographs but of broader scope. Such an article was "The Present Standing of Applied Geology" which constituted the first article of Vol. I of "Economic Geology" and thus inaugurated a publication that has become the leading journal of applied geology in the world. A single sentence from this article may be quoted since it so well reveals Ransome's breadth of view and his own capabilities. "The most successful economic geologist is likely to be he who retains his interest in the broad aspects of the science and who sees to it that his capacity for general field study does not rust for want of use." Not only did Ransome contribute the first article to "Economic Geology," but he was one of its founders and served as associate editor for thirty years.

An article entitled "The directions of movement and the nomenclature of faults," published in 1906, focussed attention on certain inconsistencies and ambiguities in the nomenclature of faults and resulted shortly thereafter in a searching restudy of fault nomenclature by a committee of the Geological Society of America of which Ransome was a member. Ransome's constant striving to improve the accuracy of his own geologic field work and that of his associates is attested in an article on "The plane-table in detailed geologic mapping," published in 1912, urging the advantages of this method at a time when it was not generally used by field geologists.

In 1913 Ransome was one of seven well known American geologists to participate in the Silliman Memorial Lectures at Yale University and chose as his topic "The Tertiary Orogeny of the North American Cordillera and Its Problems." This paper was a masterly summary of the major topographic and structural features of this great provence and was a companion to a paper by Lindgren delivered in the same series on "The Igneous Geology of the Sierras." Probably Ransome's shortest significant publication was a brief note in "Economic Geology" (1913, p. 721) in which he proposed the name protore "to designate the valueless material which generally underlies ores formed by sulphide enrichment and which itself would be converted into ore were the enrichment process continued to sufficient depth." This useful term is now in common use.

In April 1914 the importance of Ransome's contributions in the field of geology was formally recognized by his election to the National Academy of Sciences. He served the Academy and the National Research Council on several important committees and was treasurer of these two bodies from 1919 to 1924. In 1927 he served as President of the Society of Economic Geologists.

In 1922 the department of geology at the University of Arizona was being reorganized and Dr. Ransome was invited there as professor of economic geology. The long-standing ties with the Geological Survey in Washington were undoubtedly broken with deep regret and the beginning of a teaching career at the age of fifty-five required a considerable measure of courage. Arizona, however, was familiar ground to him and his four years at Tucson were notably successful among the advanced students by whom his rich background of field experience was especially appreciated. Of his years at Tucson his friend and colleague Dean G. M. Butler writes:[3]

"Dr. Ransome joined the faculty of the University of Arizona in the fall of 1922-23 as Professor of Economic Geology. Ransome's engagement marked the beginning of the expansion and improvement of the department that resulted from the interest and support of President C. H. Marvin, now head of George Washington University, and Dr. Ransome was such an admirer of Dr. Marvin that, when a cabal of faculty members forced the latter to resign four years later, Dr. Ransome refused to remain longer with the institution, and accepted a half-time position with California Institute of Technology, which he held until his death.

"While with the University of Arizona, graduate students of geology found his courses particularly inspiring and helpful, and he was appointed the first Dean of the Graduate College in the spring of 1925. The breadth of his interests was also recognized by the conferment upon him of the more general title of Professor of Geology.

"Partly because of their friendship for Dr. Ransome, Charles Schuchert and William Morris Davis were induced to join the geological faculty as lecturers, and there is no doubt but that Ransome should be credited with having done much to place

[3] Personal letter, 1941.

geological instruction at Arizona upon a sound, productive basis."

The four years of teaching at Tucson served as a valuable preparation for the longer period of teaching at the California Institute of Technology. Some of the difficulties that confront the teacher of economic geology are interestingly discussed by Ransome in an editorial "On Teaching Economic Geology" published in 1926, but that he thought his educational problems through on a high plane is clearly shown by the following words in this editorial:

"Whatever may be the purpose of a vocational or technical school, the function of a university is clearly something higher and broader than merely training men to operate a transit, make assays, construct bridges, or grow oranges. The university ideal should be to develop young men and women intellectually, morally, and physically so that they not only know how to use their minds, in Huxley's phrase 'as cold logical engines,' but have the moral and physical strength to apply that knowledge wisely to the affairs of life. The educated man is he who through knowledge of the operations of nature and with a sympathetic understanding of the thoughts, words, and deeds of past generations of his fellows, as expressed in history, literature, and art, is able to think straight, to choose in life the things that are really worth while and to find his enjoyment in those pleasures that are noble and lasting—that leave some permanent good behind them, rather than in those that are merely trivial and evanescent. This power of wise choice, based on sound thinking, is probably the most valuable result to be gained from university study and contacts."

Soon after Ransome's removal to California in 1927 to become professor of economic geology at the California Institute of Technology the country was shocked by the disastrous failure of the St. Francis dam with its attendant loss of life. Its purpose was to store surplus water delivered from the Los Angeles aqueduct. No geological examination had been made of the dam site before construction began and Dr. Ransome was greatly interested in the geologic factors involved in its failure. His illuminating report published in 1928 constituted his first contribution in a field of engineering geology, to which he later devoted much attention, serving from 1928 to the time

of his death as consulting geologist to the United States Reclamation Service and to the Metropolitan Water District of southern California.

While Ransome's resignation from the United States Geological Survey naturally brought to an end his opportunities for comprehensive studies of the geology of individual mining districts, papers relating to engineering geology—to which he was devoting part of his time—continued to flow from his pen, as well as several papers dealing with broader aspects of economic geology, such as his "Historical Review of Geology as Related to Western Mining" which forms the opening chapter of the volume "Ore Deposits of the Western States" (Lindgren Volume). One of his last publications was a review of the fourth edition of Lindgren's "Mineral Deposits." While characteristically outspoken in his criticism of some features of this monumental work of one of his closest friends, his final statement is significant: "In the reviewer's opinion, it is outstandingly the best textbook on ore deposits in English and the most satisfactory one-volume text in any language."

It was characteristic of his abundant energy that he found relaxation not in idleness but in a different kind of work. He developed great skill in working with his hands and during the last years of his residence in Washington built in his home workshop a handsome and sturdy motor launch in which he spent many happy week ends on the Potomac with his family and his friends.

Ransome's personal qualities can hardly be better expressed than in Lindgren's words:

"Physically, he was tall, well-built, and muscular, giving an impression of great reserve force. His manner of speaking was slow and deliberate. He had an exceptionally well-balanced, sane mind, not easily ruffled or disturbed. Although he was a good conversationalist and an interesting talker on professional subjects, it was not easy to get intimately acquainted with him, to reach below his armor of reserve. But those who did get to know him well were amazed at his interest in, and knowledge of, music, poetry, and the arts. His mind and his abilities were so balanced that he would have made a success of almost anything that he undertook."

His death at Pasadena, California, on October 6th, 1935, at the age of 67 followed an illness which he realized for some time was hopeless, but he prepared for the final summons with his characteristic calm fortitude. For those who were fortunate enough to know him well his career constitutes an example of an unusually rich, purposeful and useful life lived calmly, happily and wisely.

## KEY TO ABBREVIATIONS

Amer. Geol. = American Geologist.
Amer. Inst. Min. Eng. Trans. = American Institute of Mining Engineers, Transactions.
Amer. Inst. Min. Metal. Eng. = American Institute of Mining and Metallurgical Engineers.
Amer. Journ. Sci. = American Journal of Science.
Amer. Min. Congr. 23rd Ann. Conv., Rept. Proc. = American Mining Congress, 23rd Annual Convention, Report of Proceedings.
Amer. Soc. Civ. Eng., Trans. = American Society of Civil Engineers, Transactions.
Can. Min. Inst. Jour. = Canadian Mining Institute, Journal.
Econ. Geol. = Economic Geology.
Eng. Min. Journ. = Engineering and Mining Journal.
Geol. Soc Amer. Bull. = Geological Society of America, Bulletin.
Geol. Soc. Amer. Proc. = Geological Society of America, Proceedings.
Min. Mag. = Mining Magazine.
Min. Sci. Press = Mining and Scientific Press.
Nat. Geogr. Mag. = National Geographic Magazine.
Pan-Amer. Geol. = Pan-American Geologist.
Smithsonian Ann. Rept. = Smithsonian Institution, Annual Report.
Univ. Calif. Pub., Bull. Dept. Geol. = University of California Publications, Bulletin, Department of Geology.
U. S. Geol. Surv. Ann. Rept. = United States Geological Survey, Annual Report.
U. S. Geol. Surv. Bull. = United States Geological Survey, Bulletin.
U. S. Geol. Surv. Prof. Pa. = United States Geological Survey, Professional Paper.
Wash. Acad. Sci. Journn. = Washington Academy of Sciences, Journal.

## BIBLIOGRAPHY OF FREDERICK LESLIE RANSOME

*1893*

The eruptive rocks of Point Bonita (Marin County, California). *Univ. Calif. Pub., Bull. Dept. Geol.*, vol. 1, pp. 71-114, map.

*1894*

The geology of Angel Island (California). *Univ. Calif. Pub., Bull. Dept. Geol.*, vol. 1, pp. 193-234, map.

*1895*

On lawsonite, a new rock-forming mineral from the Tiburon Peninsula, Marin County, California. *Univ. Calif. Pub., Bull. Dept. Geol.*, vol. 1, pp. 301-312.

*1896*

Ueber Lawsonit, ein neues gesteinsbildendes Mineral aus Californien. (With Charles Palache.) *Zeitschrift für Krystallographie und Mineralogie,* vol. 25, pp. 531-537.

The Great Valley of California; a criticism of the theory of isostasy. *Univ. Calif. Pub., Bull. Dept. Geol.,* vol. 1, pp. 371-428.

*1897*

The age of the California coast ranges. *Amer. Geol.,* vol. 19, pp. 66-67.

Description of the Sonora quadrangle (California). (With H. W. Turner.) *U. S. Geol. Surv.,* Geologic Atlas, Sonora folio (number 41), 5 pages, maps.

*1898*

Some lava flows of the western slope of the Sierra Nevada, California. *U. S. Geol. Surv., Bull.* 89, 74 pages; (abstract) *Amer. Journ. Sci.,* 4th series, vol. 5, pp. 355-375.

Description of the gold belt; Description of the Big Trees quadrangle (California). (With H. W. Turner.) *U. S. Geol. Surv.,* Geologic Atlas, Big Trees folio (number 51), 8 pages, maps.

*1899*

On a new occurrence of nepheline syenite in New Jersey. *Amer. Journ. Sci.,* 4th series, vol. 8, pp. 417-426, map.

Microscopic petrography of the rocks from the Nicaragua Canal region. (United States), Nicaragua Canal Commission, Report 1897-1899, pp. 184-192.

*1900*

Description of the Mother Lode district (California). *U. S. Geol. Surv.,* Geologic Atlas, Mother Lode folio (number 63), 11 pages, maps.

A peculiar clastic dike and its associated ore deposits (Ouray, Colorado). (Abstract) *Science,* n. s., vol. 11, p. 348.

The fissure systems of the Silverton quadrangle, Colorado. (Abstract) *Science,* n. s., vol. 12, p. 926.

On carnotite and associated vanadiferous minerals in western Colorado. (With W. F. Hillebrand.) *Amer. Journ. Sci.,* 4th series, vol. 10. pp. 120-144.

*1901*

The ore deposits of the Rico Mountains, Colorado. *U. S. Geol. Surv., Ann. Rept.* 22, part 2, pp. 229-397.

The economic geology of the Silverton quadrangle, Colorado. *U. S. Geol. Surv., Bull. 182,* 265 pages, maps; reprint 1903.

A peculiar clastic dike near Ouray, Colorado, and its associated deposit of silver ore. *Amer. Inst. Min. Eng., Trans.,* vol. 30, pp. 227-236.

*1902*

Recent progress in petrology. *Science,* n. s., vol. 15, pp. 673-674.

Faulting and mountain structure in central Arizona. (Abstract) *Science,* n. s., vol. 15, p. 711.

*1903*

Geology of the Globe copper district, Arizona. *U. S. Geol. Surv., Prof. Pa. 12,* 168 pages, map.

Copper deposits of Bisbee, Arizona. *U. S. Geol. Surv. Bull. 213,* pp. 149-157.

The copper deposits of Bisbee, Arizona. *Eng. Min. Journ.,* vol. 75, pp. 444-445.

*1904*

The geology and ore deposits of the Bisbee quadrangle, Arizona. *U. S. Geol. Surv., Prof. Pa. 21,* 168 pages, maps.

Description of the Globe quadrangle (Arizona). *U. S. Geol. Surv.,* Geologic Atlas, Globe folio (number 111), 17 pages, maps.

Description of the Bisbee quadrangle (Arizona). *U. S. Geol. Surv.,* Geologic Atlas, Bisbee folio, (number 112), 17 pages, maps; reprint, 19 pages, 1914.

The geology and copper deposits of Bisbee, Arizona. *Amer. Inst. Min. Eng., Trans.,* vol. 34, pp. 618-642, map.

The geographic distribution of metalliferous ores within the United States. *Min. Mag.,* vol. 10, pp. 7-14.

Report of progress in the geological resurvey of the Cripple Creek district, Colorado. (With Waldemar Lindgren.) *U. S. Geol. Surv., Bull. 254,* 36 pages.

*1905*

Economic geology of the quadrangle (Silverton, Colorado). *U. S. Geol. Surv.,* Geologic Atlas, Silverton folio (number 120), pp. 26-34.

Ore deposits of the Coeur d'Alene district, Idaho. *U. S. Geol. Surv., Bull. 260,* pp. 274-303, maps.

The present standing of applied geology. *Econ. Geol.,* vol. 1, pp. 1-10.

The Coeur d'Alene district (Idaho). *Min. Mag.,* vol. 12, pp. 26-32.

On carnotite and associated minerals in western Colorado. (With W. F. Hillebrand.) *U. S. Geol. Surv., Bull. 262,* pp. 9-31.

The geological resurvey of the Cripple Creek district, Colorado. (With Waldemar Lindgren.) *U. S. Geol. Surv., Bull. 260,* pp. 85-98.

*1906*

The probable cause of the San Francisco earthquake. *Nat. Geogr. Mag.,* vol. 17, pp. 280-296; *Min. Sci. Press,* vol. 92, pp. 396-397; *Reprinted in* After earthquake and fire, pp. 130-137.

The directions of movement and the nomenclature of faults. *Econ. Geol.,* vol. 1, pp. 777-787.

Geology of the Bisbee district, Arizona. *Eng. Min. Journ.*, vol. 81, p. 1103.

Geology and gold deposits of the Cripple Creek district, Colorado. (With Waldemar Lindgren.) *U. S. Geol. Surv., Prof. Pa. 54,* 516 pages.

*1907*

Preliminary account of Goldfield, Bullfrog, and other mining districts in southern Nevada. *U. S. Geol. Surv., Bull. 303,* pp. 7-83, map.

The association of alunite with gold in the Goldfield district, Nevada. *Econ. Geol.*, vol. 2, pp. 667-692; (abstract) *Science,* n. s., vol. 27, p. 189.

*1908*

The geology and ore deposits of the Coeur d'Alene district, Idaho. (With F. C. Calkins.) *U. S. Geol. Surv., Prof. Pa. 62,* 203 pages, maps.

A comparison of some Paleozoic and pre-Cambrian sections in Arizona. (Abstract) *Science,* n. s., vol. 27, pp. 68-69.

Pre-Cambrian sediments and faults in the Grand Canyon of the Colorado. *Science,* n. s., vol. 27, pp. 667-669.

The relation between certain ore-bearing veins and gouge-filled fissures. *Econ. Geol.,* vol. 3, pp. 331-337.

A theory of ore deposition. *Econ. Geol.*, vol. 3, pp. 420-425.

An apatitic minette from northeastern Washington. *Amer. Journ. Sci.,* 4th series, vol. 26, pp. 337-341.

*1909*

The geology and ore deposits of Goldfield, Nevada. *U. S. Geol. Surv., Prof. Pa.* 66, 258 pages, map.

The Hornsilver district, Nevada. *U. S. Geol. Surv., Bull. 380,* pp. 41-43.

Round Mountain, Nevada. *U. S. Geol. Surv., Bull. 380,* pp. 44-47.

The Yerington copper district, Nevada. *U. S. Geol. Surv., Bull. 380,* pp. 99-119.

Notes on some mining districts in Humboldt County, Nevada. *U. S. Geol. Surv., Bull. 414,* 75 pages, map.

Characteristics of some ore deposits of southern Humboldt County, Nevada. (Abstract) *Science,* n. s., vol. 30, pp. 972-973.

*1910*

Criteria of downward sulphide enrichment. *Econ. Geol.*, vol. 5, pp. 205-220; *Can. Min. Inst., Quar. Bull.*, vol. 10, pp. 85-99; *Can. Min. Inst., Journ.*, vol. 13, pp. 393-407 (1911).

Geology and ore deposits of the Goldfield district, Nevada. *Econ. Geol.,* vol. 5, pp. 301-311, 438-470.

Geology at Globe, Arizona. *Min. Sci. Press,* vol. 100, pp. 256-257.

Geology and ore deposits of the Bullfrog district, Nevada. (With W. H. Emmons and G. H. Garrey.) *U. S. Geol. Surv., Bull. 407,* 130 pages, map.

Bismite. (With W. T. Shaller.) *Amer. Journ. Sci.,* 4th series, vol. 29, pp. 173-176.

*1911*

Geology and ore deposits of the Breckenridge district, Colorado. *U. S. Geol. Surv., Prof. Pa.* 75, 187 pages, map; (abstract) *Wash. Acad. Sci., Journ*, vol. 1, pp. 89-90.

Samuel Franklin Emmons. *Science,* n. s., vol. 33, pp. 601-604; Reprinted by Geological Society of Washington *in* Memorial of Samuel Franklin Emmons, pages 1-6, portrait.

Surface indications or ore shoots. *Min. Sci. Press,* vol. 102, pp. 697-699.

Geology of the Globe district, Arizona. *Min. Sci. Press,* vol. 102, pp. 747-748.

Note on some albitite dikes in Nevada. *Wash. Acad. Sci., Journ.,* vol. 1, pp. 114-118.

The literature of ore deposits in 1910. *Econ. Geol.,* vol. 6, pp. 325-339.

*1912*

Genesis of the lead-silver ores of Wardner district, Idaho. *Min. Sci. Press,* vol. 105, pp. 143-144.

The plane table in detailed geologic mapping. *Econ. Geol.,* vol. 7, pp. 113-119.

*1913*

Notes on the Bisbee district, the Globe and Miami district, Ray, and Jerome, Arizona. *U. S. Geol. Surv., Bull. 529,* pp. 179-187, 192-193.

The Turquoise copper-mining district, Arizona. *U. S. Geol. Surv., Bull. 530,* pp. 125-134, map.

(Protore, term for unenriched pyritic material.) *Econ. Geol.,* vol. 8, p. 721.

*1914*

Copper deposits near Superior, Arizona. *U. S. Geol. Surv., Bull. 540,* pp. 139-158.

Wurtzite at Goldfield, Nevada. *Wash. Acad. Sci., Journ.,* vol. 4, pp. 482-485.

*1915*

The Tertiary orogeny of the North American Cordillera and its problems. *In* Problems of American Geology, pp. 287-376, maps.

Quicksilver deposits of the Mazatzal Range, Arizona. *U. S. Geol. Surv., Bull. 620,* pp. 111-128.

The Paleozoic section of the Ray quadrangle, Arizona. *Wash. Acad. Sci., Journ.,* vol. 5, pp. 380-388.

*1916*

Some Paleozoic sections in Arizona and their correlation. *U. S. Geol. Surv., Prof. Pa.* 98, pp. 133-166, maps; (abstract) *Wash. Acad. Sci., Journ.*, vol. 6, pp. 681-682.

*1919*

The copper deposits of Ray and Miami, Arizona. *U. S. Geol. Surv., Prof. Pa.* 115, 192 pages, maps; (abstract) *Wash. Acad. Sci., Journ.*, vol. 11, number 3, pp. 57-58 (1921).

Quicksilver in 1917. *U. S. Geol. Surv.*, Mineral Resources, 1917, part 1, pp. 367-424, maps.

Quicksilver in 1918. *U. S. Geol. Surv.*, Mineral Resources, 1918, part 1, pp. 143-178.

*1920*

The functions and ideals of a national geological survey. *Science*, n. s., vol. 51, pp. 173-180, 201-207; *Wash. Acad. Sci., Journ.*, vol. 10, no. 4, pp. 85-109; *Smithsonian Ann. Rep.*, 1919, pp. 261-280 (1921); (abstract) *Eng. Min. Journ.*, vol. 109, pp. 279-280.

Geologists as expert witnesses. *Econ. Geol.*, vol. 15, no. 4, pp. 339-349.

*1921*

Geology and metal mining, with particular reference to the work of the United States Geological Survey. *Amer. Min. Cong.*, 23d Ann. Conv., Rept. Proc., pp. 407-411.

Quicksilver in 1919. *U. S. Geol. Surv.*, Mineral Resources, 1919, part 1, pp. 149-180.

*1922*

Quicksilver in 1920. *U. S. Geol. Surv.*, Mineral Resources, 1920, part 1, pp. 419-439.

Ore deposits of the Sierrita Mountains, Pima County, Arizona. *U. S. Geol. Surv., Bull.* 725, pp. 407-428.

Quicksilver in 1921. *U. S. Geol. Surv.*, Mineral Resources, 1921, part 1, pp. 107-117.

*1923*

Description of the Ray quadrangle (Arizona). *U. S. Geol. Surv.*, Geologic Atlas, Ray folio, Arizona (number 217), 24 pages, maps.

Geology of the Oatman gold district, Arizona; a preliminary report. *U. S. Geol. Surv., Bull.* 743, 58 pages, map.

Ancient high-level potholes near the Colorado River. (Abstract) *Science*, n. s., vol. 57, p. 593.

Quicksilver in 1922; with a supplementary bibliography by Isabel P. Evans. *U. S. Geol. Surv.*, Mineral Resources, 1922, part 1, pp. 113-124.

*1925*

Basin Range structure at Jerome, Arizona. *Science,* n. s., vol. 61, pp. 659-660.
Some possible lines of research on ore deposits. *Econ. Geol.,* vol. 20, no. 5, pp. 485-490.

*1926*

On teaching economic geology. *Econ. Geol.,* vol. 21, no. 5, pp. 498-501.

*1928*

Directions of progress in economic geology. *Econ. Geol.,* vol. 23, no. 2, pp. 119-131.
Geology of the St. Francis dam site. *Econ. Geol.,* vol. 23, no. 5, pp. 553-563.
Geology as related to high dams. *Engineers' News-Record,* vol. 101, no. 18, pp 657-659.

*1931*

High dams; the viewpoint of the geologist. *Amer. Soc. Civ. Eng., Trans.,* vol. 95, pp. 149-158.

*1932*

Geologic considerations affecting the choice of a route for the Colorado River aqueduct. (Abstract) *Geol. Soc. Amer., Bull.,* vol. 43, no. 1, p. 233; *Pan-Amer. Geol.,* vol. 55, no. 5, p. 369, 1931.

*1933*

Ore deposits of the Southwest (With others) *16th Internat. Geol. Cong., U. S., 1933,* Guidebook 14, Excursion C-1, 67 pages (including geologic maps).
Historical review of geology as related to western mining: Ore deposits of the Western States (Lindgren volume), pages 1-16, *Amer. Inst. Min. Metal. Eng.*
Memorial tribute to Johan Herman Lie Vogt (1858-1932). *Geol. Soc. Amer., Bul.,* vol. 44, part 2, pp. 419-421.
What is a rock? *Econ. Geol.,* vol. 28, no. 5, pp. 502-505.

*1934*

[Review of] Mineral deposits by Waldemar Lindgren. *Econ. Geol.,* vol. 29, pp. 401-406.

*1935*

The geologic features of the occurrence of copper in North America: Copper resources of the world, pp. 37-64, Washington, *16th Internat. Geol. Cong.,* 1935.
Verde fault, Arizona [abstract]: *Pan-Amer. Geol.,* vol. 64, no. 1, p. 70, August 1935; *Geol. Soc. Amer. Proc., 1935,* p. 347, June 1936.

Carl Barus

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—NINTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# CARL BARUS

1856–1935

BY

R. B. LINDSAY

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1941

# CARL BARUS

## 1856–1935

BY R. B. LINDSAY

## I. *Biographical Sketch*[1]

When the history of the progress of physics in the United States during the late nineteenth and early twentieth centuries is written the name of Carl Barus will of necessity occupy an important place. When he began his scientific career with the United States Geological Survey in 1880, American physicists and physical laboratories were relatively few in number; when he ended his professional career as Hazard Professor of Physics in Brown University in 1926, the United States had achieved an eminent position in this field of human activity. In this development, Barus' own contributions were not inconsiderable.

Carl Barus came of German stock. His father, Carl Barus, Sr., settled in this country in 1849 and found work in Cincinnati, Ohio, as a musician, though he had been trained primarily as an engineer. His mother, Sophia Möllmann by birth, was the daughter of a German clergyman who came to the United States in 1835. Carl Barus, their first child, was born on February 19, 1856 in Cincinnati where he spent the first eighteen years of his life, culminating with his graduation from the Woodward High School there in 1874.

If we may judge from Barus' unpublished autobiographical memoir[2] his boyhood was a normal, healthy one in a cultured but not wealthy family where hard work was the expected thing and luxury was unknown. There are the usual stories of the pranks of the neighborhood boys, but it does not appear that

[1] This memoir is divided into three parts: (1) a biographical sketch, (2) a review of Barus' scientific research, and (3) a bibliography of Barus' scientific publications which, so far as is known, is complete.

[2] This is the chief source of information about the personal details of Barus' life. It is an engagingly written account which makes much easier the task of even a biographer who knew him intimately. The present writer has been able to supplement this material by the recollection of numerous conversations and other associations with Professor Barus during the period from 1918-1935. The writer also wishes to acknowledge his indebtedness for interesting suggestions by Prof. W. G. Cady of Wesleyan University and Prof. Ernest Merritt of Cornell University.

the future physicist was uncommonly mischievous. On the contrary he evidently developed early the habit of systematic application which was such a conspicuous feature of his later scientific career. He speaks, for example, of ten years of faithful service as organ pumper in the churches at which his father acted as musical director. Even before his high school years, Barus showed more than a passing interest in scientific experiments, particularly in chemistry. He also took advantage of the opportunity presented by a boyhood acquaintance to learn the use of the lathe and other machine tools and was soon deep in the mystery of tempering steel. It is clear that he combined natural curiosity with considerable initiative and was not at all backward in letting people know of his existence. In school he was a conscientious student and got few thrashings—the standard method of imparting education in the sixties as well as later. He admits reading Shakespeare, Milton, Byron, Schiller and part of Goethe before the age of fifteen. Small wonder he developed a literary style unusual for a scientist! His musical education also naturally began at an early age and though he had the normal boy's detestation of piano practice he kept at the thing intensively enough to become ultimately an accomplished musician.

Barus had an astonishingly good memory and in 1923 wrote a long letter to the Founder's Day Committee of the Woodward High School in Cincinnati giving a wealth of detail about his experiences at the school some fifty years earlier. Here he was a classmate of the late ex-President and Chief Justice William Howard Taft. The standards of instruction at Woodward were exceptionally high and Barus rose nobly to the occasion, graduating in 1874 with the silver medal for outstanding work in mathematics. It seems probable, however, that he learned as much out of school as in it, for he was forever dabbling with amateur chemistry, astronomy and botany, to say nothing of attempts at poetry, playwriting and musical composition. People had not heard of "thwarted" youth in his day.

The normal expectation of a lad of Barus' financial status was that high school would complete his formal education and it was at first intended that he should get a job with a wholesale chemical house in Cincinnati. By a happy chance, however,

a former schoolmate returned from his freshman year at the Columbia School of Mines full of enthusiasm for the course of study there and the professional opportunities being opened up by the great mine booms then being exploited. The Barus family were much impressed and though their means were decidedly restricted, decided to strain a point and send their son to Columbia. Two able classmates went with him.

Life in New York was largely a peregrination from boarding house to boarding house with the usual vicissitudes in those days of uncertain plumbing and sharp landladies. But there is no question that on the whole Barus enjoyed his two years at the School of Mines. His interest in the purely engineering aspects of the course was by no means comparable with his growing enthusiasm for pure science and the physicist Professor Ogden N. Rood was his favorite teacher. There was no undergraduate physical laboratory at that time and experiments had to be done at home with simple apparatus or followed from the demonstrations of the professor who maintained an instrument maker (William Grunow) in the attic above his lecture room—very dingy quarters according to Barus' account. Here the young student was able to see fine physical equipment in the process of construction, for many well-known physicists came there to have apparatus made, among them Henry, Langley, Rowland and Michelson. Barus speaks very highly of the faculty of the School of Mines of that day, but it is clear that he was not cut out for an engineer. At the end of his second year the realization that his chief interest lay in pure physics prompted him to leave Columbia.

In 1876 Johns Hopkins University was founded and the new physical laboratory was opened under the presiding genius of H. A. Rowland. This provided an attractive opportunity for an embryonic physicist and Barus was strongly tempted to take it. There still exists a letter in Rowland's hand dated October 5, 1876, expressing his willingness to have the Columbia student work in his laboratory. Barus' father, however, was more favorable to a European training if his son were really determined to become a physicist, and Professor Rood recommended enthusiastically Würzburg and Professor Friedrich Kohlrausch, who had just then completed his well known treatise

on practical physics. So Barus took up residence in the old Bavarian university town and remained there for the next four years, taking his doctor's degree summa cum laude in 1879. He entered with zest into both the social and intellectual life of Würzburg, perhaps at first over-emphasizing the former, at any rate by his own confession. He became a member of the Arminia fraternity and engaged in its activities with the same thoroughness he showed in everything else he undertook. Duelling took much of his time and left a permament mark on his cheek. In fact one gathers that during his first year of residence the fraternity saw more of him than the physics lecture room. Finally the money began to run low and conscience to prick; intellectual zeal returned with a rush after the proposal by Kohlrausch of a doctoral research on the relation of magnetization to the hardness of steel. This was modified by Barus to a study of the thermoelectric properties and electrical conductivity in their relation to hardness. His thesis was published in the Annalen der Physik in 1879, having been reported to the physical-medical society in Würzburg in January of that year. The physical laboratory facilities at Würzburg during most of Barus' stay were rather crude and uncomfortable. Apparatus building for graduate students was largely a matter of cobbling together equipment out of wood, cork, glass, rubber and wax with metal foil, wire and solder. Nevertheless the apparatus served its purpose. Each generation will not cease to wonder at the remarkable results achieved by the meager tools of the previous one. During Barus' residence the Bavarian government built for Kohlrausch a new physical laboratory and Barus helped in the process of moving and settling. At Kohlrausch's invitation he decided to stay for a time after receiving his degree and act as assistant in the new laboratory. Here he continued his research work on steel with the collaboration of a Czecho-Slovakian colleague, Vincent Strouhal. The pair gathered material for a number of papers which appeared in the Annalen der Physik from 1880-1883. By 1880, Barus' father was anxious to have him return to America and a good opportunity developed with the possibility of a position under Clarence King, the director of the United States Geological Survey, who was looking for a man in geophysics. So the

young Ph.D. from Wurzburg returned to begin a professional career in this country.

After a short stay with his family in Cincinnati he received his appointment as physicist in the Geological Survey and was ordered to Nevada to make electrical measurements on ore bodies as a member of the staff of Dr. G. F. Becker, the geologist. Here he spent the better part of a year in a rather adventurous existence delving into gold and silver mines and more or less roughing it in the wilds of a section made famous about that same time by Mark Twain. Barus worked both in the famous Comstock lode in Virginia City and at Ruby Hill near Eureka. As an interesting commentary on the serious conscientiousness with which the young physicist took his work it may be noted that after he had returned to Cincinnati to work out his report, he was assailed with doubts whether certain experimental allowances had been properly made. So seriously did he feel this that he went back to Nevada to check this single point. It turned out that the return trip was unnecessary. Nevertheless the incident stamped Barus as a serious and cautious scientist and augured well for the future.

The next phase in Barus' connection with the Geological Survey came with the establishment of a rather elaborate geophysical laboratory, first (and for a short time only, i.e., December 1881-November 1882) in the American Museum of Natural History in New York and later in a private dwelling house in New Haven. In this work it was planned that he would be assisted by his former colleague at Würzburg, Dr. Strouhal, and the latter did actually help considerably in purchasing in Europe the much needed apparatus which it was practically impossible to procure in America at that time. However, an offer of the professorship of physics at the Czech University of Prague overturned Strouhal's plans to join Barus and the latter had to look elsewhere. He finally found an able collaborator in another American, William Hallock, who had also just then taken his degree with Kohlrausch. He was a Columbia man and remained with the Survey until 1891, ultimately becoming professor of physics and head of the department at Columbia. The two young physicists set up what must have been a well-appointed laboratory for those days at 310 Dixwell

Avenue in New Haven. The location was apparently chosen with a view to the possibility of collaboration with the Yale faculty, and Barus and his colleague received a very kind reception from the Yale scientists. They embarked on an elaborate geophysical program which first involved a thorough calibration of the platinum thermocouples which were to be used for high temperature measurements. However, it appears that little of a definite nature was accomplished. The lure of social activity was still too strong for such youngsters to resist and the Yale acquaintances were probably too kind. Then, too, Clarence King, on whose initiative the whole research project had been undertaken, had been absent from the country for a considerable time and was no longer director of the Survey. The new director, Major J. W. Powell, did not take kindly to the New Haven laboratory and ordered it dismantled in 1884 and the removal of the apparatus to Washington, D. C., where new quarters were provided in the National Museum.

Barus remained in Washington for the next ten years. His work for the Geological Survey continued until 1892 and was a period of intense scientific activity. His colleague Hallock left him and he worked alone on a great variety of fundamental researches in geophysics, including a thorough study of the viscosity of steel in various stages of hardness, and a continuation of the high temperature thermometry begun in New Haven. Such preliminary experiments were necessary before proceeding to the main geophysical research, which began to be tackled about 1888 and included a determination of the volume expansion of rock in the transition from the solid to the liquid state as well as the change in the specific heat during the transition. The behavior of bodies under very high pressure was also studied. The importance of this work will be noticed further on in the review of Barus' scientific achievements. Suffice it to say that the basis of his scientific reputation was laid in this work with the Survey. It led to his election to the National Academy of Sciences in 1892. It also undoubtedly played an important part in establishing the method of his research: for the rest of his life his most significant work was done without collaborators. It had both the advantage of encouraging independence and the disadvantage (which indeed showed itself

later) of encouraging queerness in notation and making his papers rather difficult to read. It was in Washington also that Barus began his married life. He was married on January 20, 1887, to Annie Gertrude Howes, a graduate of Vassar College in the class of 1874. Two children were born of this marriage, Maxwell Barus and Deborah Barus, of New York and Boston respectively. Mrs. Barus, who later become an active and nationally recognized worker in sociological and educational fields, died in 1928.

Though government scientific salaries were low, Barus enjoyed his work thoroughly. He was an independent worker, content to let the results of his labors speak for themselves without the trumpet blowing of extra-laboratory activities. In this he was probably unwise, since in his sincere confidence in Major Powell he made no attempt to build favor for himself outside of the Survey. Moreover there was no civil service protection then. Hence when Powell lost his grip with Congress, several of his staff were unceremoniously dismissed, among them Barus. This was in 1892 and marked the end of his association with the U. S. Geological Survey. To make the shock greater and the gloom more dismal the geophysical equipment which had been laboriously constructed over a period of nearly a dozen years was constitutionally classified as "old junk" and was carted off to the Department of the Interior to be disposed of as such. The only silver lining in the cloud was provided by the apparatus originally lent to Barus by Clarence King. This alone remained after the house-cleaning. Curiously enough it stayed with Barus to the end of his life and some of it still remains in the Physical Laboratory at Brown University.

As a physicist with a laboratory and some scientific equipment but minus a job, Barus felt himself doomed to cut a sorry figure. If he had known of the ups and downs which the next three years were to hold in store for him, he would have felt even worse. At the moment, however, a saviour appeared in the shape of Professor Mark W. Harrington, who had just been called from Michigan to head the remodeled U. S. Weather Bureau, recently transferred to the Department of the Interior. Harrington decided to put a little physics

into the Bureau and organized a sub-department of meteorological research in which Barus was made Professor of Meteorology in September, 1892. Showing considerable versatility he threw himself into the new field with great vigor and soon had a program underway to look into the condensation of atmospheric moisture. However, even here trouble arose over the "anomaly" of a research under the auspices of the Weather Bureau being carried on in the National Museum! So Barus had to find new quarters. It was Alexander Graham Bell who came to the rescue in the spring of 1893 with the offer to rent a house in Georgetown for the project until the Bureau could take care of it. However, Barus' peace of mind was short-lived, for the incoming Cleveland administration made short work of his new post and in the summer of 1893 he was again without a job, though he still had a laboratory.

Barus had previously attracted the favorable attention of S. P. Langley, the Secretary of the Smithsonian Institution, and in August, 1893, accepted the latter's offer to become scientific consultant at the Institution. The salary was small compared with his previous stipends, but it was better than nothing and kept him in the field of physics. Two projects were to be worked on; first, the connection between radiation and temperature (the field in which Langley made probably his greatest contribution) and second, aerodynamical researches. Barus was not too enthusiastic over the latter, but it appears that of the two he had to spend more time and energy on this than on the former. Langley was an indefatigable experimenter and in those days experiments with airplanes were very disappointing. When the history of aeronautics is written, the hours Barus spent trying to make Langley's models fly certainly ought to receive attention. In his memoirs he states frankly that he did not enjoy the work. Finally early in 1895 he gave it up entirely. His stay at the Smithsonian had not been a total loss, however, for there he had a chance to meet many celebrated visiting physicists and to conduct some of the multifarious scientific correspondence inevitably associated with such an institution.

Life must have looked rather blue for a time. Here was a mature physicist in his late thirties, already recognized by the

American Academy and the National Academy and with many colleagues fully acquainted with the value of his work, but without a job! For a few months Barus set up as a consulting physicist and actually patented some devices which, however, developed into nothing. A few nibbles had come from some educational institutions but they like the inventions came to naught. Finally in March of 1895 a letter came from his old teacher Professor Rood of Columbia, stating that Rood's brother-in-law, Professor Eli Whitney Blake, was about to retire from the Hazard Professorship of Physics at Brown University and conveying the suggestion that Barus should become a candidate for the vacant position. Rood took upon himself the position of "campaign manager" and proved eminently successful in this capacity, for Barus ultimately received the appointment in May, 1895, after many weeks of letter writing, interviewing, etc. There were probably some who felt considerable doubt about entrusting the position to a man who had had no teaching experience whatever, even though his professional attainments were vouched for by half a dozen of the most famous physicists in the country.

The opportunity at Brown must have seemed like a haven of refuge to the much buffeted physicist. But Barus by no means rested on his oars. He entered into the business of learning how to teach with the same thoroughness and enthusiasm he had shown in his scientific research. Evidently he wrote to his predecessor Blake for advice in connection with the general elementary course, for a letter still exists from Blake to Barus cautioning him not to expect too much of his sophomores. His over-optimism about the amount of physics which can be stuffed into college undergraduates was soon tempered by experience. His lectures could not have been unpopular for the enrollment in elementary physics increased steadily during the first years of his stay. Much time went into the devising of effective lecture demonstrations and many such pieces with elaborate charts, etc., are still extant to testify to Barus' thoughtful attention to pedagogical matters. Disillusionment came, as it undoubtedly does to all who teach. In Barus' case it came on an occasion when he announced to his class that due to the necessity of attending a scientific meeting he would be forced

to absent himself from the next class meeting. He expressed regret, but the class responded with applause! Most of us sooner or later learn not to take ourselves too seriously in the business of teaching.

The rest of Barus' active career was spent at Brown University, where he held the Hazard Professorship until his retirement at the age of 70 in 1926. In 1903 it was deemed desirable to put graduate instruction on a somewhat more systematic basis and a graduate department was established with Barus as Dean. He served in this capacity also until his retirement and witnessed great growth in graduate study. In 1926 the "department" had grown large enough to be made into a separate school of the University—a tribute to the efforts Barus had made toward its evolution. His annual reports as Dean were a definite contribution to post graduate higher education in America, for he had the uncanny power to separate the essential from the unessential.

As a classroom teacher Barus followed the European lecture system with perhaps a somewhat more careful regard for the time schedule. Promptly at the last stroke of the college bell he would stride into the classroom and with no preliminaries launch directly into his discourse. No questions were tolerated during the lecture—students might beard the professor in his den afterwards if they chose (or dared). The lectures were clear and in the elementary course, at any rate, rather lavishly illustrated with demonstrations, simple in construction but having the merit of usually working. Occasionally a flash of humor would emerge, but this was rare and for that reason all the more keenly appreciated. The pace set, particularly in the intermediate and advanced courses, was rather severe and demanded close attention on the part of the auditor. Some students found it simpler to use the lectures as suggestions for what should be studied outside class and not as a systematic course in themselves. This occasionally led to embarrassment when the week's notebook, handed in for inspection, did not seem to have much connection with the week's lectures. One comment in a case of this sort is worth recording. Barus wrote at the end of a screed more than usually irrelevant to what he had been trying to talk about: "I set a given week's

work and you hand me in return a tragedy of Euripides." The notes were always corrected but not always severely enough. A representative of a well-known scientific instrument company has told the writer that he remembers climbing out of the lecture room window while Barus was scribbling on the blackboard (after attendance had been taken, of course). Such stories could be duplicated at any number of college campuses during the first decade of this century. Physics lecture rooms today are not so easy to leave surreptitiously!

There seems little doubt that Barus' real heart was in his research, which he kept at almost continually winter and summer until his retirement. When Commencement came and the college community largely dissolved until fall, Barus shipped his family off to the seashore but went on working in his basement laboratory. He was a prolific writer on scientific subjects and believed in describing the results of experiments with considerable detail and in frequent reports, as a glance at the appended bibliography amply indicates. During his tenure at Brown alone he found time to bring out some 300 publications, a record of productivity scarcely equalled in American physics. He worked almost entirely alone and made nearly all his own apparatus, on which the financial expenditure was usually rather meager. Very rarely has so much been accomplished with so little. Although an assessment of Barus' scientific contributions will be found in the second part of this memoir, something should be said here about the style of his writing. For a scientist he possessed an unusual grasp of language and evidently keenly enjoyed putting words on paper. He had a very witty way of bringing out essential points which makes his book reviews and general articles on the progress of physics a pleasure to read even today when the physical ideas in them have often long since passed into the realm of the historic. His address at the International Congress in St. Louis in 1904, for example, was a masterly summary of the whole evolution of physics during the 19th century and still repays study both for content and style. That his powers of graphic delineation did not wane with age is evident from his Honor's Day address at Brown in 1926 on "Three Phenomenal Ages of Cultural Advance." Those who corresponded with Barus will recall what a

delightful letter writer he was and how he could invest even the simplest topics with a whimsical significance.

For the first fifteen years of his connection with Brown, Barus occupied a very prominent place in the activities of American physicists and the list of his dignities and high offices is impressive. In 1897 he was a Vice-President of the American Association for the Advancement of Science and Chairman of the Section on Physics at the Detroit meeting of that year. His address on this occasion concerned long range variables in temperature and pressure measurement. In 1898 he visited England as guest of Cambridge University on the occasion of the Stokes Jubilee and was made an honorary member of the Royal Institution of Great Britain. He took this occasion to travel extensively in France and Germany, renewing old friendships and making new ones. In 1899 Barus was a member of a committee which founded the American Physical Society, in whose fortunes he took for many years an active part. He was the fourth president of the society, holding that office in 1905-1906. He comments that his presidential address in New York on December 30, 1905, describing his work on condensation nuclei, was twice as long as it should have been. On reading it one can only marvel at the patience and capacity of the physicists of that day. Barus served as a member of the council of the Physical Society until his death. Naturally in his later years he was forced to give up active participation in the affairs of the society.

In 1900 the American Academy of Arts and Sciences awarded Barus its Rumford Medal for his researches in heat. In the same year he contributed a paper on high temperature measurement to the International Congress of Physics in Paris. In 1902 he was invited by President Gilman of Johns Hopkins to join the advisory council of the Carnegie Institution of Washington, in which he served with Woodward and Michelson as the committee for physics. The plan for the administration of the funds of the Institution which Barus drew up and the committee recommended was not finally adopted. Nevertheless he himself did some of his research under Carnegie grants and many of his later research reports appeared as Carnegie publications.

In 1903 came election to the American Philosophical Society

and his appointment as Dean of the Graduate Department at Brown University. The next year saw the International Congress of Arts and Sciences in St. Louis and Barus gave the principal address for physics, taking as his subject the progress of the science during the nineteenth century.

For many years Barus was an active member of the National Academy of Sciences and attended meetings faithfully. When the National Bureau of Standards was founded he worked hard to get the Academy to endorse the project. Later, when the Proceedings of the Academy was established as a journal, Barus became a frequent contributor. In 1900 the Academy met at Brown and Barus received the congratulations of his fellow members for the thoroughness with which the arrangements had been carried through.

Barus received two honorary degrees, an LL.D. from Brown in 1907 and a similar degree from Clark in 1909. In 1911 he traveled in Europe and attended the Portsmouth meeting of the British Association for the Advancement of Science.

During the first World War the National Research Council was formed by Hale and Millikan, and Barus was a member. He gave a good deal of time to certain instrument problems though it is clear that he was not enthusiastic over the particular work within the scope of his resources, and glad when the end of the war enabled him to drop it. The war years were not happy ones for a pure scientist and Barus labored under the extra handicap of carrying a German name.

After the war Barus' courses suffered a considerable slump in attendance and he finally gave up elementary teaching shortly after reaching 60. Though he emphasizes in his memoirs his love of teaching, it is clear that by 1918 the spontaneity had departed and his elementary instruction had grown mechanical and uninspiring. He began to confine himself to his Deanship, his research (which continued unabated) and his advanced courses, the most successful of which was that in vector analysis which actually amounted to an introduction to theoretical physics. As a matter of fact he continued to teach this course with unfailing zest after he became professor emeritus and indeed up to the very year of his death.

After 1920 traveling became a hardship and Barus rarely

if ever attended scientific meetings. He tended more and more to withdraw into himself and those who wished to see him had to visit him in his laboratory. At the same time he withdrew also from active participation in the affairs of his own department, leaving the details to his colleague and successor, Professor A. deF. Palmer. During most of his tenure the department consisted of the two professors and it does not appear that Barus made any serious attempt to increase it; if he did he was singularly unsuccessful. This is rather curious since during this whole period, physics departments in other institutions headed by men of his caliber made great strides. Possibly this is another indication that Barus' real zest was for his own research, also emphasized by the fact that he directed almost no students for the doctorate. Administrative procedure as such was distasteful to him, though he performed faithfully, systematically and efficiently that which he was called upon to do.

In 1926 Barus attained the compulsory retiring age of 70 and became professor emeritus. The Corporation of Brown University extended to him the privilege of laboratory space and for a time he continued to carry on his investigations. But the effort was rather taxing and the old fire was burning low. He still came to the laboratory every day, read widely to keep himself informed on the progress of physics, and enjoyed thoroughly his lectures in vector analysis. As the slackening of research provided more time he mellowed considerably in his attitude toward casual visitors and would talk by the hour with visiting colleagues about his reminiscences, which were a delight to listen to. When he was in the mood he was a brilliant conversationalist. His interests in the world about him continued to be wide and deep to the very end of his life. At the age of 60 he had taken up the study of Greek and Italian and maintained a zeal for literature until his death. His skill in music has already been referred to. Besides playing the piano very well he also mastered in adult life the violin, flute, clarinet, oboe, cornet, trumpet and trombone. Moreover the number of his musical compositions reached 40. Many of his former students well remember how he used to write music while proctoring elementary tests. It will never be quite

clear just what the nature of the artistic inspiration was on such occasions!

In personal appearance, Carl Barus was tall with a sparely knit frame. In later life he walked with a slight stoop but had a good stride. As he walked across the campus with the cane he invariably used he was a dignified figure that even an undergraduate would stop twice to look at. Though not particularly athletic he enjoyed swimming, boating and bicycling. In fact swimming formed his chief recreation in the summers he spent on Cape Cod during the last seven or eight years of his life. Barus used to remark that smoking was his only vice. He pursued it methodically. One rarely visited him in his laboratory without finding him pipe in mouth. To avoid the nuisance of matches, a small gas flame burned continually within easy reach. The empty tobacco cans formed useful containers for small physical apparatus, and the usual thoroughness was also displayed in the carefully kept accounts of the weekly consumption, which were found among his papers after his death.

Though Barus suffered considerably from insomnia in later life, possibly connected with his tremendous mental energy, he was rarely ill in the usual sense of the word and maintained a reasonably good state of health until the summer of 1935 when he had to undergo a serious operation. Progress was very slow and he had just begun to show signs of definite recovery at his home in Providence when death came suddenly with a cerebral hemorrhage on September 20, 1935. With him there passed away one of the ablest men ever to occupy a chair in Brown University and one of America's distinguished scientists.

## II. *Scientific Research (1879-1929)*

A complete assessment of Barus' contributions to physics is beyond the scope of the present memoir but it seems desirable to provide a brief summary of his principal scientific achievements. For convenience his research career may be divided into three main periods: (1) geophysical research during his service with the U. S. Geological Survey, probably his most significant work; (2) investigation of condensation and ionization

in the atmosphere begun with the U. S. Weather Bureau and continued during the early years at Brown University; (3) development and application of optical interferometry to a variety of problems in light, electricity, gravitation and acoustics, carried out during the latter part of his career at Brown. It will be impossible here to do justice to the great many side branches into which his insatiable curiosity led him from time to time.

As has already been indicated Barus' first geophysical work consisted of a study of the electrical activity of ore bodies in Nevada. So far as is known this represents the first physical research conducted by the Survey and is a tribute to the perspicacity of Clarence King in recognizing the importance of physical methods in geology. Barus set out to determine the possibility of locating the presence and approximate position of ore bodies by measurements of electrical potentials in the surface. On the whole the measurements were successful and represent a definite advance over other work of similar nature done earlier in the nineteenth century. The investigations were not pursued further, for Barus' interests were always in fundamental things and not so much in applications. It is interesting to note, however, that the problem and its mathematical ramifications have been taken up again seriously by geophysicists during the past decade. Even before leaving Nevada, Barus carried out in collaboration with G. F. Becker a series of observations on the kaolinization produced by the action of hot water on feldspar. In later years he returned to this problem in the consideration of the compressibility of hot water in glass vessels in which the solution of the glass in the water was a source of considerable difficulty, but nevertheless led to interesting results having a bearing on volcanic action.

Clarence King was very much interested in dynamical geology and particularly in the age of the earth from the standpoint of the thermal conductivity of rock. With his usual thoroughness Barus mapped out an elaborate program for the study of the thermal behavior of rock material both in the liquid and solid states. He soon found it necessary, however, to precede this with an investigation of high temperature measurement. In 1886 he completed the first rigorous comparison of platinum-iridium and other platinum alloy thermocouples with the air

thermometer over a range of some 1000°C. This fully confirmed the validity of thermoelectric pyrometry and established the method as one of the greatest utility in high temperature measurement. Here Barus definitely anticipated Le Chatelier, who usually receives the credit for thermoelectric calibration. Unfortunately the report of Barus' work in Bulletin 54 of the Geological Survey, a book of 313 pages, did not see the light until 1889, by which time much of Le Chatelier's work was well known. The latter part of the report is devoted to the description of investigations of high temperature viscosity of gases and its possible use in precision pyrometry. This was a bit of pioneering work which was not followed up.

An allied problem investigated at length at the same time was the viscosity of solids. This followed appropriately from Barus' thesis investigation at Würzburg on the properties of steel in their dependence on hardness. Various workers in different countries had studied the subject but there was considerable confusion due to divergence in notation. Barus' investigation was an elaborate attempt to obtain precise results and to unify the field. He succeeded in showing the essential validity of Maxwell's theory of viscosity and in particular established the significant metallurgical result that the phenomena associated with temper in steel, considered as of the nature of a strain, follow at once from Maxwell's theory. Barus was also led to attempt the distinction between the various states of matter on the basis of viscosity, which under fixed conditions of temperature, pressure and strain remains constant in time for fluids, but which for solids increases steadily under the application of constant stress. All this was pioneer research of the highest order and first importance in the field of metallurgy. Much of it was reviewed later in his Clark University lectures in 1909 on the physical properties of the iron carbides.

The effect of high pressures also came into the picture, and Barus busied himself much in the late eighties with devising means for the production and accurate measurement of such pressures, which he finally succeeded in carrying out up to 2000 atmospheres. With this and his high temperature equipment he was able to embark on a long series of researches on the thermodynamics of liquids. This would undoubtedly have been

extended to more specific geological problems had not Barus' tenure in the Survey been abruptly terminated in 1892. As it was, his achievements in geophysics attracted international attention, being favorably commented on by Lord Kelvin, among others.

To the period of Barus' association with the Survey belongs also some fundamental research on the nature of colloids. In a paper with E. A. Schneider "Über die Natur der kolloidalen Lösungen" (Zs. fur Physikalische Chemie," 8, 278, 1891), he and his colleague definitely established that colloidal silver solution consists of an aggregate of extremely small particles of actual silver. This marked an important forward step in the study of colloids.

Though Barus worked for the Weather Bureau for only one year the studies begun during this engagement initiated a program which, after an interruption of several years, formed his major scientific interest from 1900-1910. The problem was to study the condensation of water vapor in its dependence on the size of the nuclei precipitating it. In particular the plan involved gradually decreasing the size of the nuclei until they approached the diameter of the water molecule itself, i.e. condensation taking place in completely dust free air. Presumably Barus was the first person ever to try deliberately to condense water vapor on its own molecules. For this purpose he employed a carefully controlled steam jet and estimated the size of the water particles by means of the colors produced in the light scattered by the particles. He definitely understood that the cooling involved in the condensation is adiabatic, in its first stages at any rate, and he seems definitely to have anticipated the important work of C. T. R. Wilson in his famous paper of 1896. It is unfortunate that he had to break off his experiments so abruptly, as he clearly had his hands on one of the most important tools of twentieth century physics. When he returned to the subject around 1900 the cream had been removed by the English investigators. The cloud chamber had already been invented by Wilson and was being increasingly used to study condensation as affected by various ionizing means. Nevertheless, Barus was still fascinated by the use of light scattering (coronas) in studying condensation and determined to follow up this field. For this

purpose he found it advisable to use the fog chamber rather than the cloud chamber. This is a vessel about 50 centimeters long and 15 centimeters in diameter. It is connected through a short but wide pipe to a large tank, which in turn is pumped to a pressure about 30 centimeters below atmospheric pressure while the fog chamber itself is kept at atmospheric pressure by means of a large stopcock. On opening the stopcock suddenly the result is adiabatic expansion of the air in the chamber. The fog produced is looked at against a bright source of light illuminating the chamber transversely and the "fog limit" is estimated from the first appearance of the diffraction rings. Moreover, the number of condensation nuclei formed or the extent of the nucleation can be estimated from the size of the rings. With apparatus of this type Barus investigated over a period of several years nucleation in the free atmosphere as a function of season and discovered some interesting periodicities. The effect of ionizing agents like X-rays and radioactive materials was also studied. The first stages of this research were reported at length in Barus' presidential address to the American Physical Society at the end of 1905. This work was rather roughly handled in "Nature" by C. T. R. Wilson, who might be expected to display small sympathy for systematic research with an instrument like the fog chamber when he had developed in the cloud chamber one of so much greater precision. His criticisms of Barus' results provoked a controversy which was probably taken a little too seriously by the American. In addition to the experimental uncertainties of the fog chamber, it is a fact that Barus paid rather too little attention to the role of ionization in nucleation. Along this route the great discoveries in atomic physics were being made. It is perhaps unfortunate that a physicist of Barus' stature was unwilling to throw his research energy into the cooperative venture which culminated in the modern theory of the constitution of matter. It is clear, however, that already in the early years of the new century, Barus was satisfied to play a lone hand. This is reflected in the make-up of his papers. In contrast to earlier procedure he began to omit all but the most cursory reference to the work of other previous and contemporary researchers, and his chief publications began to assume

more and more the appearance of progress reports of his own experiments without adequate summaries of the essential results and their relation to those of other workers in the same or allied fields. They thus became increasingly difficult to read with discernment, even though there might be no question about the manipulative and interpretative skill of the experimenter. The writer is willing to hazard the guess that very few have ever made a really careful study of Barus' four memoirs on nucleation published under the auspices of the Carnegie Institution from 1906-1910. Certainly one finds very few references in present day literature to them, in marked contrast to his earlier research on high temperature and high pressure and their effects on the properties of matter. Yet a study made in the Brown Physical Laboratory in 1936 indicates that the fog chamber with certain simple improvements *can* be made to give reliable results.

The year 1910 may for convenience be taken to mark the beginning of the third and last stage of Barus' scientific activity. He then largely relinquished his work on condensation and embarked on a program of miscellaneous research suggested by the development of an ingenious displacement interferometer. In its early simple form this consisted of a plane transparent diffraction grating backed with a mirror. When light incident on and reflected from the front surface of the grating (after passing through the grating and being reflected by the mirror) is examined in a telescope, interference fringes are observed whose position is very sensitive with respect to any displacement of the mirror. Later the apparatus was modified in such a way that light from a single source reflected from two mirrors (more or less as in the conventional Michelson interferometer) is examined after passing through a plane transparent grating. A displacement of one of the mirrors produces a shift in the fringe system which can be used as a measure of the displacement.

With this instrument in various stages of modification and improvement over a period of some fifteen years, Barus investigated an astonishingly large range of physical phenomena involving very small linear or angular displacements. Thus, as if

he were unwilling entirely to tear himself away from his condensation problem, he applied his interferometer to the measurement of the size of fog particles. Later he used the same instrument for the measurement of ordinary and extraordinary indices of refraction of doubly refracting crystals as well as magneto-striction elongations in iron. There followed in rapid succession (around 1914) the estimation of acoustic displacements of telephone diaphragms, the index of refraction of air at high temperatures, the accurate comparison of screws of any length, a precision quadrant electrometer, the measurement of changes of angular inclination of a pendulum as small as $3 \times 10^{-4}$ seconds of arc, etc.

The interferometer was later applied by means of an open mercury manometer to precise pressure measurement, the precision stated by Barus being of the order of a few hundred thousandths of a centimeter of mercury per fringe displacement. This at once suggested the exploration of acoustic radiation fields by means of a pin-hole probe connected to the interferometer pressure gauge. This is probably the most precise non-electrical method of measuring acoustic pressure which has ever been devised. Unfortunately it was never followed up on a large scale by Barus and has been more or less neglected by others. Barus' unwillingness to embark on pretentious projects involving large financial layout and the use of numerous assistants, also had much to do with the failure of his attempt to apply displacement interferometry to a re-determination of the Newtonian constant of gravitation. For a number of years around 1920 he experimented with this problem and undoubtedly had in his hands an extremely precise method, but the disadvantages of his laboratory situation, with inevitable and largely uncontrollable temperature gradients, made his results illusory.

It is perhaps worthy of note that the displacement interferometer has more recently been made by C. E. Bennett [3] into a high precision instrument for the measurement of the dispersion of gases as a function of pressure.

[3] C. E. Bennett, Phys. Rev. 37, 263, 1931; 45, 200, 1934; 58, 263, 1940.

It is difficult to avoid the feeling that practically all the scientific work of Barus during the last dozen years culminating in 1929 was of purely exploratory character, dictated by his own fancies and interests and with little effort toward the more precise development of his ideas. There can be no question that he profoundly enjoyed what he was doing and that it brought him more satisfaction than his teaching and administrative work. But he had reached the stage where he was unwilling to go at things in a large way and seek financial support for elaborate equipment. His autobiography indicates a growing feeling through the twenties that he was out of touch with the main trends of contemporary physics and that his scientific career was about over. He must have realized with growing misgivings that few persons any longer read his papers with clear appreciation of what he was doing. It is futile to quarrel with individual idiosyncrasies but one may be pardoned for expressing the regret that during his long teaching career Barus made little or no effort to build up graduate study in physics, so that a succession of doctoral students could have profited by his ingenuity and been stimulated by his drive. This would have insured much greater attention to his later scientific research and would have put the research itself on a firmer basis with a more adequate exploitation of its features of ultimate value. Such regrets are, of course, vain in the face of the record. The holder of this record will go down in scientific history as a great American physicist. That, with his insatiable curiosity, unusual intuitive powers, extraordinary experimental skill, and incredible capacity for work, he should have become an even greater figure lies strictly outside the province of an admiring biographer to stress.

## BIBLIOGRAPHY

### KEY TO ABBREVIATIONS

A. A. A. S, Proc. = American Association for the Advancement of Science, Proceedings.
Amer. Acad., Proc. = Proceedings, American Academy of Arts and Sciences.
Amer. Chem. Soc., Journ. = American Chemical Society Journal.
Amer. Hist Rev. = American Historical Review.
Amer. Inst. Mining Eng. = American Institute of Mining Engineers.
Amer. Journ. Meteor. = American Journal of Meteorology.
Amer. Journ. Sci. = American Journal of Science.
Amer Phil Soc. Proc. = American Philosophical Society Proceedings.
Ann. d. Physik = Annalen der Physik.
Ann. d. Physik u. Chemie = Annalen der Physik und Chemie.
Journ. Phys. Chem. = Journal of Physical Chemistry.
Nat. Acad. Sci. Proc. = National Academy of Sciences Proceedings.
Phil. Mag. = Philosophical Magazine.
Phys. Rev. = Physical Review.
Phys. Zeits. = Physikalische Zeitschrift.
Rev. Amer. Chem. Res. = Review of American Chemical Research.
Smithson. Contrib. Know. = Smithsonian Contributions to Knowledge.
Terr. Mag. = Terrestrial Magnetism.
U. S. Geol. Surv. Bull. = U. S. Geological Survey Bulletin.
U. S. Geol. Surv. Mono. = U. S. Geological Survey Monographs.
Verh. d. Physik. Med. Gesell. Würzburg, N. F = Verhandlungen der Physikalische-Medizinische Gesellschaft, Würzburg.
Zeits. f. Phys. Chem. = Zeitschrift fur Physikalische Chemie.

*1879*

Die Thermo-electrische Stellung und das Electrische Leitungsvermögen des Stahls in ihres Abhängigkeit von der Hartung. (Thesis) Ann. d. Physik u. Chemie, 7, 383-414. Translation in Phil. Mag. (3) 8, 341-368.

*1880*

Ueber eine einfache Methode der galvanischen Calibrirung eines Drahtes. (With V. Strouhal) Ann. d. Physik u. Chemie, 10, 326-330.
Ueber Anlassen des Stahls und Messung seines Hartezustandes. (With V. Strouhal) Ann. d. Physik u. Chemie, 11, 930-977.
Anlassen des Stahls und Messung seines Hartezustandes. (With V. Strouhal) Verh. d. Physik. Med. Gesell., Würzburg, N. F. 15, 7.

*1881*

Ueber der Aenderung der Thermo-electrischen Stellung des Eisens und des Stahls durch Magnetisirung. (With V. Strouhal) Ann. d. Physik u. Chemie, 15, 54-61.

*1882*

Geology of the Comstock Lode and the Washoe District with Atlas. By George F. Becker. Dr. Barus wrote Chapter IX "On the thermal effect of the action of aqueous vapor on feldspathic rocks," pp. 290-308; and Chapter X "On the electrical activity of ore bodies," pp. 309-367. Dr. Barus and F. R. Reade carried out many of the computations involved in the discussion of the increment of heat contained in this monograph. U. S. Geol Surv. Mono. 3.

*1883*

Ueber den Einfluss der Harte des Stahls auf dessen Magnetisirbarkeit. (With V. Strouhal) Ann. d. Physik u. Chemie, 20, 621-662.

Ueber den Einfluss des Anlassens auf die Haltbarkeit der Magnete. (With V. Strouhal) Ann. d. Physik u. Chemie, 20, 662-684.

Ueber den galvanischen Temperatur-coefficienten des Stahls, des Stab und Gusseisens. (With V. Strouhal) Ann. d. Physik u. Chemie, 20, 525-536.

*1884*

Das Wesen der Stahlhartung vom elektrischen Standpunkte aus betrachtet, besonders im Anschluss an das entsprechende Verhalten einiger Silberlegirungen. (With V. Strouhal) Abhandlungen der kongl. böhm. Gesell. der Wissen. 6 Folge, 12, 1-27. Prag.

Ueber die Definition des Stahls auf Grundlage des Electrischen Verhaltens des Eisens beim Wachsenden Kohlenstoffgehalt. (With V. Strouhal) Abhandlungen der kongl. böhm Gesell. der Wissen. 6 Folge, 12, 1-25.

On the thermal effect of the action of aqueous vapor on feldspathic rocks (Kaolinization). School of Mines, Quarterly, 6, 1-24.

Time, temper, and color of oxide films on steel. U. S. Geol. Surv., Bull. 27, 51-61.

*1885*

The electrical activity of ore bodies. Amer. Inst. Mining Eng., 13, 417-477.

The electrical and magnetic properties of the iron carburets. (With V. Strouhal) U. S. Geol. Surv., Bull. 14, 1-238.

The relation between electrical resistance and density, when varying with the temper of steel. (With V. Strouhal) U. S. Geol. Surv., Rept. Div. Chem. and Phys., Bull. 27, 1-51.

*1886*

On the strain effect of sudden cooling exhibited by glass and steel. (With V. Strouhal) Amer. Journ. Sci., 31, 439-452; 32, 181-192.

Hydro-electric effects of temperature in case of steel. (With V. Strouhal) Amer. Journ. Sci., 32, 276-283.

The viscosity of steel and its relation to temperature. (With V. Strouhal) Amer. Journ. Sci., 32, 444-466.

Physical properties of the iron carburets. (With V. Strouhal) U. S. Geol. Surv., Bull. 35, 1-61.

Subsidence of fine solid particles in liquids. U. S. Geol. Surv., Bull. 36, 1-53.

The effect of sudden cooling exhibited by glass and by steel considered both chemically and physically. (With V. Strouhal) U. S. Geol. Surv., Rept. Div. Chem. and Phys., Bull. 42, 99-131.

Note on the structure of tempered steel. (With V. Strouhal) Amer. Journ. Sci., 31, 386.

*1887*

The viscosity of steel and its relation to temperature. (With V. Strouhal) Amer. Journ. Sci., 33, 20-36.

The viscosity of steel and its relation to temperature. Amer. Journ. Sci., 34, 1-19.

The effect of magnetization on the viscosity and the rigidity of iron and steel. Amer. Journ. Sci., 34, 175-186.

*1888*

Notes on the viscosity of gases at high temperatures and on the pyrometric use of the principle of viscosity. Amer. Jour. Sci., 34, 407-410.

Maxwell's theory of the viscosity of solids and certain features of its physical verification. Amer. Journ. Sci., 36, 178-208.

Certain generic electrical relations of the alloys of platinum. Amer. Journ. Sci., 36, 427-442.

Secular annealing of cold hard steel. Phil. Mag, 26, 397-403.

*1889*

Die Zähigkeit der Gase im Gebiete hoher Temperaturen. Ann. d. Physik u. Chemie, 36, 358-398.

The subsidence of fine solid particles in liquids. Amer. Journ. Sci., 37, 122-129.

The electrical resistance of strained glass. Amer. Journ. Sci, 37, 339-351.

The energy potentialized in permanent changes of molecular configuration. Amer. Journ. Sci., 38, 193-198.

The viscous effects of strains mechanically applied as interpreted by Maxwell's theory. Phil. Mag., 27, 155-177.

On the thermo-electric measurements of high temperatures. U. S. Geol. Surv., Bull. 54, 1-313.

*1890*

Fluid volume and its relation to pressure. Amer. Journ. Sci., 39, 478-511.

The effect of pressure on the electrical conductivity of liquids. Amer. Journ. Sci., 40, 219-222.

The pressure variations of certain high temperature boiling points. Phil. Mag., 29, 141-159.

The change of the order of absolute viscosity encountered on passing from fluid to solid. Phil. Mag. 29, 337-355.

The isometrics of liquid matter. Phil. Mag., 30, 338-361.

The hydro-electric effect of stretching metals. Amer Chem. Soc., Jour., 12, 1-13.

A method of obtaining and measuring very high pressures. Amer Acad., Proc., 25, 93-108.

The molecular stability of metals, particularly of iron and steel. Nature, 41, 369-371.

Note on the absolute viscosity of solids, liquids, and gases. Amer Journ. Sci, 39, 234.

*1891*

Compressibility of hot water and and its solvent action on glass. Amer. Journ. Sci., 41, 110-116.

The chemical equilibrium of solids in its relation to pressure and temperature. Phil. Mag, 31, 9-35.

Note on the pressure coefficients of the voltaic cell. Amer. Acad., Proc., 25, 259-261.

Note on the continuity of solid and liquid. Amer. Journ. Sci., 41, 325-326.

A comparison of the Bourdon, the Tait, and the Amagat high pressure gauges. Phil. Mag., 31, 400-406.

The continuity of solid and liquid. Amer. Journ. Sci., 42, 125-147.

Über die Natur der kolloidalen Lösungen (with E. A. Schneider). Zeits. f. phys. Chem., 8, 278-298.

The viscosity of solids. U. S. Geol. Surv. Bull. 73, 1-139.

Note on the variation of molecular pressure. Amer. Acad., Proc., 26, 313-325.

The contraction of molten rock Amer. Journ. Sci, 42, 498-499.

The solution of vulcanized India rubber. Amer. Journ. Sci., 42, 359-369.

*1892*

The relation of melting-point and pressure in case of igneous rock fusion. Amer. Journ. Sci., 43, 56-57.

The dependence of viscosity on pressure and temperature. Amer. Acad., Proc., 27, 13-18.

The volume lag and its bearing on molecular constitution. Amer. Chem. Soc, Journ., 14, 191-202.

Note on the change of heat conductivity in passing isothermally from solid to liquid. Phil Mag. 33, 431-432.

Note on the relative position of high temperature melting and boiling points. Amer. Acad., Proc., 27, 100.

The change of heat conductivity in passing isothermally from solid to liquid. Amer. Journ. Sci, 44, 1-15.

The fusion constants of igneous rocks, I. Phil. Mag., 34, 1-18.

Note on the change of electrical conductivity observed in rock magmas of different composition on passing from liquid to solid. (With J. P. Iddings.) Amer. Journ. Sci., 44, 242-249.

Thermal variation of viscosity and of electric resistance. Amer. Journ. Sci., 44, 255.

Thermoelectrics of platinum iridium and of platinum rhodium. Phil. Mag., 34, 376-381.
Die phys. Behandlung und die Messung hoher Temperaturen. Leipzig, J. A. Barth, I-IV; 1-92.
The compressibility of liquids. U. S. Geol. Surv., Bull. 92, 1-96.
The mechanism of solid viscosity. U. S. Geol. Surv., Bull. 94, 1-138.
The volume thermodynamics of liquids. U. S. Geol. Surv., Bull. 96, 1-100.

*1893*

Isothermals, isopiestics, and isometrics relative to viscosity. Amer. Journ. Sci., 45, 87-96.
Preliminary note on the colors of cloudy condensation. Amer. Journ. Sci., 45, 150-151. (Cf., Phil. Mag., 35, 315.)
The colors of cloudy condensation. Amer. Journ. Meteor., 9, 488-521.
The fusion constants of igneous rock, II. The contraction of molten igneous rock on passing from liquid to solid. Phil. Mag., 35, 173-190.
The fusion constants of igneous rock, III. The thermal capacity of igneous rock, considered in its bearing on the relation of melting-point to pressure. Phil. Mag. 35, 296-307.
Ueber das verhalten des colloidalen Silbers gegen den electrischen Strom. (With E. A. Schneider.) Ann. d. Physik, 48, 327-337.
Colored cloudy condensation as depending on air temperature and dust contents, with a view to dust counting. Amer. Journ. Meteor., 10, 12-34.
Mr. McGee and the Washington symposium. Science, 22, 22.
Criticism of Mr. Fisher's remarks on rock fusion. Amer. Journ. Sci., 46, 140-141.
High temperature work in igneous fusion and ebullition, chiefly in relation to pressure. U. S. Geol. Surv., Bull. 103, 1-57.

*1894*

Spiral goniometry in its relation to the measurement of activity. Amer. Journ. Sci., 48, 1-10.
An elementary expression in thermoelectrics. Amer. Journ. Sci., 47, 366-371.
Colored cloudy condensation as depending on the temperature and on dust contents of the air. Phil. Mag., 38, 19-35.
Contributions to Landolt and Börnstein's Phys. Chem. Tabellen, Berlin, J. Springer.
The colors of cloudy condensation. Nature, 49, 363.
Remarks on colloidal silver. Amer. Journ. Sci., 48, 451-454.
The present status of high temperature research. Amer. Journ. Sci., 48, 332-336.
A simple chronograph pendulum. Amer. Journ. Sci., 48, 396-397.
Note on the telephonic measurement of electromotive force. Amer. Journ. Sci., 48, 346.
Telephonic measurement of electromotive force. Phil. Mag., 38, 558-567.

*1895*

Report on the condensation of atmospheric moisture. U. S Weather Bureau, Bull. 12, 1-104.

Standards for electrical measure. Committee Report, National Academy of Sciences, February 20, 1-9.

The significance of certain experiments of Professor E. W. Blake. Brown Magazine, 7, 41-48.

*1896*

The lecture experiment with liquid carbon dioxide. Amer. Journ. Sci., 2, 1-4.

A curve-tracing top. Science, 4, 444-446.

*1897*

The blackboard treatment of physical vectors. Science, 5, 171-175.

Preliminary trial of an interferential induction balance. Amer. Journ. Sci., 3, 107-116.

Note on the excursions of the diaphragm of a telephone. Amer. Journ. Sci., 3, 219-222.

On a possible development of the idiostatic electrometer. Phys. Rev., 4, 400-404

Effects of hardness on the electrical and magnetic constants of steel, etc. Terr. Mag., 2, 1-10.

Review of Helmholtz's "Electromagnetic theory of light." Journ. Phys. Chem, 1, 537.

Clamp for fragile glassware. Science, 6, 31.

Long range temperature and pressure variables in physics. Vice-Presidential address. A.A.A.S., Proc., 46, 1-30; Science, 6, 333; Nature, 56, 528.

The saecular softening of cold hard steel, with remarks on electrical standards. Phil. Mag. 44, 436-483.

*1898*

Combination tones of the siren and an organ pipe. Amer. Journ. Sci., 5, 88-92.

On a method of obtaining pores or capillary canals of a specified diameter. Phys. Rev. 6, 52-54.

Review of "Vorlesungen ueber die prinzipe der mechanik," Pt. I, Ludwig Boltzmann (Barth, Leipzig, 1897). Journ. Phys. Chem., 2, 53-54.

The mathematical theory of the top. Science, 8, 470-474.

Curious inversion of the wave mechanism of the electromagnetic theory of light. Amer. Journ. Sci., 5, 343-348.

Ballistic galvanometry with a counter-twisted torsion system. Phys. Rev., 7, 10-18.

The compressibility of colloids, with applications to the jelly theory of the ether. Amer. Journ. Sci., 6, 285-298.

Remarks on colloidal glass. Amer. Journ. Sci , **6**, *270*.
Inertia as a possible manifestation of the ether. Science, **8**, 681-685.

*1899*

The thermodynamic relations of hydrated glass. Amer. Journ. Sci., **7**, 1-3.
The objective presentation of harmonic motion. Science, **9**, 385-406.
Review of "Die moderne entwicklung der electrischen prinzipen," F. Rosenberger (Barth, Leipzig, 1898). Journ. Phys. Chem., **3**, 48.
The aqueous fusion of glass, its relation to pressure and temperature, I. Phil. Mag. **47**, 104-109.
The aqueous fusion of glass, its relation to pressure and temperature, II. Phil. Mag., **47**, 461-479.
"The Laws of Gases." Memoirs by R. Boyle and E. A. Amagat. Translated and edited by Carl Barus. 107 pp. New York, American Book Co., 1899. (Harper's Scientific Memoirs, No. 5.)
Review of "A treatise on the kinetic theory of gases" (S. H. Burbury, Cambridge Univ. Press 1899). Journ. Phys. Chem., **3**, 605-606.
Die Einwirkung des Wassers auf heisses Glas. Phys. Zeits., **1**, 3-5.

*1900*

Review of "Kanon der physik," Felix Auerbach (Veit, Leipzig, 1899). Journ. Phys. Chem., **4**, 42-43.
Review of "Cinematique et mechanismes; potentiel et mecanique des fluides," Henri Poincare. (Carre et Naud, Paris, 1899). Journ. Phys. Chem., **4**, 137.
Review of "Strahlung und temperatur der sonne," J. S. Scheiner. (Engelmann, Leipzig, 1899). Phys. Rev., **10**, 126-127.
Review of "Mesure des temperatures elevees," H. Le Chatelier et O. Boudouard. Bibliotheque de la Revue Generale des Sciences. (Carre et Naud, Paris, 1900). Journ. Phys. Chem., **4**, 394-395.
Review of "Vorlesungen über hydrodynamische fernkrafte, nach C. A. Bjerknes' Theorie," V. Bjerknes. Vol. I. (Barth, Leipzig, 1900). Journ. Phys. Chem., **4**, 395-396.
Motion of a submerged index thread of mercury in the lapse of time. Amer. Journ. Sci., **9**, 201-206.
On the absorption of condensation-producing atmospheric dust by solid nuclei and surfaces, and on the diffusion velocity of supposedly non-ionized dust particles. Science, **11**, 201-206.
Hot water and soft glass in their thermodynamic relations. Amer. Journ. Sci., **9**, 161-175.
On a method of studying diffusion of air through water, and on a method of barometry. Amer. Journ. Sci , **9**, 397-400.
Review of the scientific papers of J. W. Strutt, Lord Rayleigh Science, **11**, 550-585.
The transmission of the ionized exhalation of P through air and other nuclei. Phys. Rev., **10**, 257-267.

Rapport sur les progres de pyrometrie. Translated by D. Berthelot. Paris, Congres International de Physique, 1-30.

The interferences observed on viewing one coarse grating through another, and on the projection of one piece of wire gauze by a parallel piece. Science, 12, 617-627.

Torsional magnetostriction in strong transverse fields and allied phenomena. Amer. Journ. Sci., 10, 407-418.

The rates of a rocking watch. Phil. Mag., 50, 595-604.

Review of "A Treatise on the Theory of Screws," Sir Robert Stawell Ball. (Univ. Press; Cambridge, Macmillan, New York, 1900) Science, n.s. 12, 1001-1003.

*1901*

Review of "Handbuch der Spectroscopie," H. Kayser. Vol. I. (Hirzel, Leipzig, 1900) Journ. Phys. Chem., 5, 66-68.

Hysteresis-like phenomena in torsional magnetostriction and their relation to viscosity. Amer. Journ. Sci., 11, 47-110.

Certain stroboscopic phenomena in the end or projection of a wave. Science, 13, 128-129.

The projection of ripples by a grating. Science, 13, 297-298

Note on the number of particles in the saturated phosphorescent emanation Science, 13, 501-503.

On the behaviour of the phosphorus emanation in spherical condensers. Amer. Journ. Sci., 11, 310-314.

Reminiscent remarks on the top. Science, 13, 852-853.

The general equations of rotation of a rigid body. Science, 13, 914-915.

On the stability of vibrations. Science, 14, 403-405.

On the change of the colors of cloudy condensation with the number of available nuclei, and the effect of an electric field. Phil. Mag., 1, 572-578.

Absorption of the ionized phosphorus emanation in tubes. Phil. Mag., 2, 40-49.

On the transmission of the ionized emanations of phosphorus through air and other media. Phil. Mag. 2, 391-403.

On the simultaneous volumetric and electric graduation of the steam tube with a phosphorus ionizer. Phil. Mag 2, 477-488.

Experiments with ionized air. Smithson. Contrib. Know. 24, Publication 1309. i-x, 1-93.

Effect of temperature and moisture on the emanations of phosphorus and on a distinction of nuclei and ions. Amer. Journ. Sci., 12, 327-346.

Temporary set as associated with magnetostriction. Phys. Rev. 13, 283-306.

Greenhill's mathematical theory of the top. Science, 14, 973-975.

Review of "Handbuch der spectroscopie," H. Kayser. Vol. 1. (Hirzel, Leipzig, 1900). Journ Phys. Chem. 5, 66-68.

*1902*

Behavior of the phosphorus emanation in spherical condensers. Phil. Mag. 3, 80-91.

The sizes of water particles producing the coronal and the axial colors of cloudy condensation. Phil. Mag. 4, 24-29.

On spontaneous nucleation and on the nuclei produced by shaking solutions. Phil. Mag. 4, 262-269.

Graded condensation in benzine vapor, as evidenced by the distorted coronas and marked axial colors attending cloudy condensation. Science, 15, 175-178.

On geometric sequences of the coronas of cloudy condensation and on the contrast of axial and coronal colors. Amer Journ Sci., 13, 81-94.

Flowerlike distortion of the coronas due to cloudy condensation. Amer. Journ. Sci., 13, 309-312.

An American journal of physics. Science, 15, 629-630.

Certain properties of nuclei. Science, 15, 912-914.

Note on the possibility of a colloidal state of gases. Amer. Journ. Sci., 13, 400-402.

On a method of hygrometry. Science, 16, 33-34.

On the structure of the nucleus. Science, 16, 633-636.

The variation of atmospheric nucleation. Science, 16, 948-952.

On the velocity and structure of the nucleus. Amer. Journ. Sci., 13, 225-233.

*1903*

Data with a possible bearing on the cause of lightning. Science, 17, 32.

Ionization of water nuclei, I. Amer. Journ. Sci., 15, 105-120.

Ionization of water nuclei, II. Amer. Journ. Sci., 15, 217-223.

Apertures of coronas in relation to the number of nuclei and their size. Amer. Journ. Sci., 15, 335-341.

Atmospheric nucleation during cold weather. Phys. Rev., 16, 193-198; 246.

The structure of the nucleus. Smithson. Contrib. Know., 29, Publication 1373, 1-173.

Ionization and nucleation of the phosphorus emanation. Phys. Rev., 16, 247.

The relation of ionization to nucleation in the case of phosphorus. Phys. Rev., 16, 287-299.

Diffusion of vapor into nucleated air. Amer. Journ. Sci., 15, 472-476.

Review of "Lehrbuch der kosmischen Physik," Svante August Arrhenius, Vol. 1 and Vol. 2. (Hirzel, Leipzig, 1903), Journ. Phys. Chem., 7, 467-469.

Bemerkung über die Schmidt'scher Theorie der Phosphoremanationen. Ann. d. Physik, 11, 1142-1144.

Experiments with a Holtz machine and the ratio of the velocities of the ions. Phys. Rev., 16, 247.

Absence of electrification in cases of sudden condensation and of evaporation. Phys. Rev., 16, 384.

Nuclei produced chemically by mixture of coal gas and of air. Phys. Rev., 16, 385.

Ions and nuclei. Nature, 69, 103.

The coronal method of estimating atmospheric nucleation. Phys. Rev., 17, 233-244.

Note on the constants of coronas. Amer. Journ. Sci., 16, 325-327.

Review of "Vorlesungen uber hydrodynamische Fernkrafte nach C. A. Bjerknes' Theorie," V. Bjerkens. Vol. II. (Bath, Leipzig, 1902), Journ. Phys. Chem., 7, 219-220.

Review of "Handbuch der Spectroscopie," H. Kayser. Vol. 2. (Hirzel, Leipzig, 1902), Journ. Phys. Chem., 7, 300-302.

*1904*

Periodic color distribution in relation to the coronas of cloudy condensation, with a revision of coronas. In "Festschrift Ludwig Boltzmann Gewidmet," (Barth, Leipzig, 1904), 204-214.

On the numbers of nuclei produced by shaking different liquids. Amer. Journ. Sci., 17, 81-84.

Direct micrometric photography of fog particles. Amer. Journ. Sci., 17, 160-170.

Review of "Vorlesungen über theoretische Physik," H. von Helmholtz. Band VI, Theorie der Wärme. (Barth, Leipzig, 1903). Journ. Phys. Chem, 8, 56-59.

Ions and nuclei. Rev. Amer. Chem. Res., 10, 87-89.

Photography of fog particles. Nature, 69, 494.

On the denucleating effect of air stirred over water. Amer. Journ. Sci., 17, 392-394.

*1905*

Preliminary results with an objective method of showing the distribution of nuclei produced by X-rays, for instance. Amer. Journ. Sci., 19, 175-184.

Note on the variation of the sizes of nuclei with the intensity of the ionization. Science, 21, 275-276.

Address given in honor of Professor A. S. Packard. Science, 21, 404-406.

Penetrating radiation associated with X-rays. Science, 21, 563-566.

Alternations of large and small coronas, etc. Amer. Journ. Sci., 19, 349-356.

Review of "An Introduction to the Theory of Optics," Arthur Schuster. (Arnold, London, 1904). Journ. Phys. Chem., 9, 420.

Review of "Vorlesungen über die Prinzipe der Mechanik," Ludwig Boltzmann. Zweiter Teil, enthaltend: "Die Wirkungs-prinzipe, die Lagrangeschen Gleichungen und deren Anwendungen." (Barth, Leipiz, 1904). Journ. Phys. Chem., 9, 420.

Review of "Radioactivity," E. Rutherford. (Cambridge, University Press, 1904). Science, ns. **21**, 697-698.

Note on fleeting and on persistent nuclei. Phys. Rev., **112**, 52-56.

Properties and distributions of nuclei. International Congress of Radiology and Ionization, Liege, 1-42.

Groups of efficient nuclei in dust-free air. Amer. Journ. Sci., **20**. 297-300.

Relations of ions and nuclei in dust-free air. Amer. Journ. Sci., **20**, 448-453.

Eigenschaften von Kondensationskerner und ihre atmospherische Vertheilung. Phys. Zeits., **6**, 718-726.

Progress of physics in the nineteenth century. Science, **22**, 363-369; 385-397.

*1906*

Professor Gills on physical geology. Amer. Journ. Sci., **21**, 461-462.

Condensation nuclei. (Presidential address.) Phys. Rev., **22**, 82-110.

Review of "Physical Optics," Robert W. Wood. (Macmillan, New York, 1905). Journ Phys. Chem., **10**, 221-222.

Review of "Les Quantites elementaries d'Electricite: Ions, Electrons, Corpuscles. Memoires reunis et publies par Henri Abraham et Paul Langevin. (Soc. Française de Physique: Collection de Memoires relatifs a la Physique.) (Gauthier-Villars, Paris, 1905). Journ. Phys. Chem., **10**, 301-302.

Review of "Radio-activity," E. Rutherford. 2nd ed. (Cambridge, University Press, 1905). Science, n.s. **23**, 262.

A continuous record of atmospheric nucleation. Smithson. Contrib. Know., **34**, Publication 1651, 1-226.

The nucleation of the uncontaminated atmosphere. Carnegie Publications, **40**, x-xii; 1-152.

Proprietes des noyaux de condensation dans l'air. Translated by E. Bloch. Le Radium, **3**, 18-20.

Eye anomalies. Science, **23**, 390-391.

Distribution of colloidal nuclei and of ions in dust-free $CO_2$. Phys. Rev., **23**, 31-36.

Note on the computed drop in pressure in adiabatic expansion. Amer. Journ. Sci., **22**, 81.

Corpuscular radiation from cosmical sources. Science, **23**, 952.

Time variation of the initial nucleation of wet dust-free air. Science, **24**, 180-181.

Colloidal nuclei and ions in dust-free air saturated with alcohol vapor. Amer. Journ. Sci., **24**, 136-142.

Actual drop of pressure in the fog chamber. Amer. Journ. Sci., **22**, 339-341.

New method of standardizing coronas. Amer. Journ. Sci., **22**, 342-343.

Vulcanism. Science, **24**, 400-403.

Water precipitation per cubic centimeter in the fog chamber. Phys. Rev., **23**, 444-446.

Note on the change of colloidal nuclei of wet dust-free air in the lapse of time. Amer. Journ. Sci., 22, 541.

*1907*

Condensation of vapor as induced by nuclei and ions. Carnegie Publications, 62, i-x, 1-164.
Polarization and interference phenomena with white light Science, 25, 348-350
Changes of colloidal nuclei of wet dust-free air in the lapse of time. Amer. Journ. Sci., 23, 202-210.
Distribution of ions and nuclei in dust-free air Phys. Rev., 24, 232-236.
Equations of the fog chamber. Phys Rev, 24, 383-384.
Efficiency of the plug cock fog chamber. Phil. Mag., 13, 357-364.
Review of "Les Origines de la Statique," P. Duhem. Vol. 2. (Hermann, Paris, 1906). Journ. Phys. Chem., 11, 422.
Review of "Radioactive Transformations," E. Rutherford. (Scribner's, New York, 1906). Journ. Phys Chem., 11, 423.
Review of "Electrons, or the Nature and Properties of Negative Electricity," Oliver Lodge. (Macmillan, New York, 1906). Journ. Phys. Chem., 11, 497-498.
Review of "Essais de Jean Rey, Docteur en Medecine." (Hermann, Paris, 1907). Journ. Phys. Chem., 11, 498.
On the distribution of nuclei in dust-free air. Amer. Phil. Soc., Proc., 46, 70-79.
Sun spots. Science, 25, 972-973.
Vapor nucleation in the lapse of time. Amer. Journ. Sci., 23, 342-344.
Review of "Vorlesungen über theoretische Physik," H. von Helmholtz. Band IV., "Vorlesungen uber Elektrodynamik und Theoric des Magnesismus." (Barth, Leipzig, 1907). Journ. Phys. Chem., 11, 574-575.
Review of "Die Kathodenstrahlen," G. C. Schmidt, second ed. (Vieweg, Braunschweig, 1907). Journ. Phys. Chem., 11, 575.
Specification of diagrams in applied geometry. Science, 26, 149-151.
On a method for the observation of coronas. Amer. Journ. Sci., 24, 277-281.
On successive cycles of coronas. Amer. Journ. Sci., 24, 309-312.
The decay of ionized nuclei in the fog chamber. Amer. Journ. Sci., 24, 419-425.
The flying machine. Science, 26, 672-673.
Über die Vertheilung der Kondensationskerne in Staubfrei Luft, etc. Ann. d. Physik, 24, 225-242.
Note on volcanic activity. Amer. Journ. Sci., 24, 484.
Lodge's ether and Huyghen's gravity. Science, 26, 875.
Condensation nuclei from the evaporation of fog particles. Phys. Rev., 25, 391-398.

*1908*

Pendulum coincidences determined by shadow reinforcement. Phys. Rev., 26, 299-301.
Axial colors of steam jet and coronas. Amer. Journ. Sci., 25, 224-226.
The behavior of nuclei of pure water. Amer. Journ. Sci., 25, 409-412.
Regions of maximum ionization due to radiation. Science, 28, 26-28.
Standardization of the fog chamber by aid of Thomson's electron. Amer. Journ. Sci., 26, 87-90.
Thomson's constant e found in terms of the decay constant of ions within the fog chamber. Amer. Journ. Sci., 26, 324-328.
Condensation of vapor as induced by nuclei and ions, III. Carnegie Publications, 96, i-v, 1-139.

*1909*

Coronas with mercury light. Amer. Journ. Sci., 27, 73-81.
Absence of polarization in artificial fogs. Amer. Journ. Sci., 27, 402.
Adjustment for plane grating similar to Rowland's for concave grating. Amer. Phil. Soc., Proc., 48, 166-176.
The electron method of standardizing the coronas of cloudy condensation. Amer. Phil. Soc., Proc., 48, 177-188.
Electronic measurement of voltaic potential. Amer. Phil. Soc., Proc., 48, 189-193.
Saecular softening of hard steel. Phys. Rev., 29, 516-524.
Historical graphics. Science, 30, 372-373.

*1910*

Sur les phénomènes de condensation dus aux ions. Congrès international de Radiologie et d'Électricité, Bruxelles, 1910. (Abstract) Le Radium, 7, 240.
Probability of an inherent relation of the electrical resistance and the hardness of steel. Phys. Rev., 30, 347-349.
Condensation of vapor as induced by nuclei and ions, IV. Carnegie Publications, 96, Pt. II, i-vii, 1-84.
Interference of reflected-diffracted and diffracted-reflected rays on a plane transparent grating and on an interferometer. (With Maxwell Barus.) Science, 31, 394-395.
On the general use of the grating with the interferometer. Science, 32, 92-93.
Interference of the reflected-diffracted and the diffracted-reflected rays on a plane transparent grating. (With Maxwell Barus.) Phil. Mag., 20, 45-59.
The use of the grating in interferometry. Amer. Journ. Sci., 30, 161-171.
Variations graphically. Science, 31, 867-868.
The grating interferometer. (With Maxwell Barus.) Phys. Rev., 31, 591-598.
Interferometry and a new interferometer. Eastern Association of Physics Teachers. Report of the Fifty-Sixth Meeting, Providence, 13-21.

The compression of solid colloids. In, "Gedenkboek aangeboden aan J. M. van Bemmelen," 303-307. (De Boer.)

*1911*

Elliptic interference in connection with reflecting grating. Science, 33, 113.

On an adjustment for plane grating similar to Rowland's for concave gratings, etc. (With Maxwell Barus.) Amer. Journ. Sci, 31, 85-95.

Interferometry with the aid of a grating. Phil. Mag., 21, 411-434.

Der Gang der Luft durch eine Wasserwand. Ostwald's Kolloidal Zeits., 8, 286-291.

Transpiration of air through water. Amer. Phil. Soc., Proc., 50, 117-124.

Elliptic interference with reflecting gratings. Amer. Phil. Soc., Proc., 50, 125-138.

Elliptic and other interferences with reflecting gratings. Phil. Mag., 22, 118-129.

Independence of coronas of the thickness of fog layer. Amer. Journ. Sci., 31, 564-566.

Über sedimentation. Ostwald's Kolloidal Zeits., 9, 14-16.

The production of elliptic interferences in relation to interferometry. Carnegie Publications, 149, i-vi; 1-77.

The production of elliptic interferences in relation to interferometry, Part II. Carnegie Publications, 149, Pt. 2, i-vi; 79-168.

*1912*

The diffusion of gases through water. Report of the Eighty-first Meeting of the British Association for the Advancement of Science, Portsmouth, 1911. Murray, London, p. 357.

Certain physical properties of the iron carbides, together with inferences deducible therefrom. *In,* Clark University, Lectures delivered at the celebration of the twentieth anniversary of the foundation of Clark University . . . Worcester, Mass., 128-161.

Rate of decay of different sizes of nuclei. Amer. Journ. Sci., 33, 107-108.

Displacement interferometer adapted for high temperature measurement, adiabatic transformation of gas, etc. Amer. Journ. Sci., 33, 109-119.

The rectification of the spectrum in relation to the shift of ellipses in displacement interferometry. Phil. Mag., 23, 942-955.

Comparison of two screws. Amer. Journ. Sci., 34, 333-337.

Viscosity of gases and Bunsen flame. Science, 36, 320.

Interferometry of ionized air. Amer. Journ. Sci., 34, 101-116.

Growth of air bubbles on the walls of a beaker, etc. Amer. Journ. Sci., 34, 304.

The indices of doubly refracting crystals detected by displacement interferometry. Phil. Mag., 24, 827-837.

*1913*

On a simple screw micrometer. Amer. Journ. Sci., 35, 267-269.

Resolution of interference fringes. Amer. Journ. Sci., 35, 308-310.

The diffusion of gases through liquids and allied experiments. Carnegie Publications, 186, I-VI; 1-88.

Scattering in case of regular reflection, etc. Nature, 92, 451.

*1914*

Electrometer with displacement interferometry. Amer. Journ. Sci., 37, 65-86.

The production of elliptic interferences in relation to interferometry. Carnegie Publications, 149, Pt. 3, I-VI; 169-273.

An application of the displacement interferometer to the horizontal pendulum. Amer. Journ. Sci., 37, 501-513.

Note on mutual repulsion of rigid parallel plates separated by film of air. Amer. Journ. Sci., 37, 350-351.

Contractions of the order of the Lorentz-Fitzgerald. Amer. Journ. Sci., 38, 352-354.

The mathematician in modern physics. Science, 40, 721-727.

*1915*

Mutual repulsion of rigid parallel plates. Amer. Journ. Sci., 39, 93-104.

The use of compensators bounded by curved surfaces in displacement interferometry. Amer. Journ. Sci., 40, 299-308.

Trains of beating light waves. Science, 42, 350.

Interferences of crossed spectra, etc. Amer. Journ. Sci., 40, 486-498.

Experiments with the displacement interferometer. Carnegie Publications, 229, I-VI; 1-113.

Interferences with two gratings. Science, 42, 841.

*1916*

Interferences of the direct spectra of two gratings. Phys. Rev., 7, 587-598.

The interferences of reversed spectra. Amer. Journ. Sci., 41, 414-434.

Distance between two parallel transparent plates. Phys. Rev., 7, 79-86.

An apparent lateral reaction between identical pencils of light crossing each other at small angles. Science, 43, 282-284.

Note on the interference of parallel and crossed rays. Science, 43, 345-436.

Channeled grating spectra obtained in successive diffractions. Nat. Acad. Sci., Proc., 2, 378-380.

Rotation of interferometer fringes. Amer. Journ. Sci., 42, 63-73.

The interferometry of reversed and non-reversed spectra. Carnegie Publications, 249, 1-158.

Interferometer methods based on the cleavage of the diffracted ray. Nat. Acad. Sci., Proc., 2, 475-478.

The interferences of spectra both reversed and inverted. Nat. Acad. Sci., Proc., 2, 576-578.

Methods in reversed and non-reversed spectrum interferometry. Amer. Journ. Sci., 42, 402-420.

Path differences within which spectrum interferences are observable. Nat. Acad. Sci., Proc., 2, 609-613.

Non-reversed spectra of restricted coincidence. Nat. Acad. Sci., Proc., 2, 614-617.

*1917*

Methods in reversed and non-reversed spectrum interferometry. Amer. Journ. Sci., 43, 145-162.

Refractivity determined irrespective of form by displacement interferometry. Nat. Acad. Sci., Proc., 3, 117-122.

Note on complementary Fresnellian fringes. Nat. Acad Sci., Proc., 3, 432-436.

The displacement interferometry of large distances. Nat. Acad. Sci., Proc., 3, 436-437.

The measurement of small angles by displacement interferometry. Nat. Acad. Sci., Proc., 3, 412-415.

The interferometry of reversed and non-reversed spectra. Part II. Carnegie Publications, 249, Part II, 1-146.

Experiments with the Foucault pendulum. Induction pendulum. Science, 45, 265-270.

Displacement interferometry in connection with U-tubes. Nat. Acad. Sci., Proc., 3, 334-339.

Theoretical relations in the interferometry of small angles. Nat. Acad. Sci., Proc., 3, 563-565.

Note on interferometer methods of measuring the elastics of small bodies. Nat. Acad. Sci., Proc., 3, 693-696.

Transverse displacement interferometry. Nat. Acad. Sci., Proc., 3, 360-365.

The interferometry of small angles, etc. Methods by direct and reversed superposed spectra. Nat. Acad. Sci., Proc., 3, 665-672.

*1918*

Types of achromatic fringes. Nat. Acad. Sci., Proc., 4, 132-133.

Interference of pencils which constitutes the remote divergences from a slit. Nat. Acad. Sci., Proc., 4, 134-136.

Note on methods of observing potential differences induced by the earth's magnetic field in an insulated moving wire. (With Maxwell Barus.) Nat. Acad. Sci., Proc., 4, 66-70.

On the equations of the rectangular interferometer. Nat. Acad. Sci., Proc., 4, 13-19.

Polarization of moving electrodes. Science 48, 253-254.

Hygrometry in terms of the weight of a film of gelatine. Science, 48, 374-376.

The interferometry of vibrating systems. Nat. Acad. Sci., Proc., 4, 328-333.

Gravitational attraction in connection with the rectangular interferometer. Nat. Acad. Sci., Proc., 4, 338-342.

The rectangular interferometer with achromatic displacement fringes in connection with the horizontal pendulum. Nat. Acad. Sci., Proc., **4**, 349-354.

*1919*

Note on a contact lever, using achromatic displacement fringes. Nat. Acad. Sci., Proc., **5**, 39-43.

Interferential contact lever experiments relating to the elastics of small bodies. Nat. Acad. Sci., Proc., **5**, 44-49.

Note on the self-adjusting interferometer in relation to the achromatic fringes. Nat. Acad. Sci., Proc., **5**, 53-58.

An adjustment in relation to the Fresnel coefficient. Nat. Acad. Sci., Proc., **5**, 120-125.

On Herschell's fringes. Science, **49**, 385-386.

Spectrum phenomena due to moving motes. Science, **49**, 72-74.

Displacement interferometry by the aid of the achromatic fringes. Part III. Carnegie Publications, **249**, Part III, 1-100.

Displacement interferometry by the aid of the achromatic fringes. Part IV. Carnegie Publications, **249**, Part IV, 1-122.

An electrodynamometer using the vibration telescope. Nat. Acad. Sci., Proc., **5**, 211-217.

The elongation due to magnetization. Nat. Acad. Sci., Proc, **5**, 267-272.

The interferometry of rapid vibrations, chiefly in relation to telephone currents. Nat. Acad. Sci., Proc., **5**, 331-340.

On the pressure variation of specific heat of liquids. Nat. Acad. Sci., **5**, 340-344.

The motion of a gravitating needle. Science, **50**, 214-216.

The interaction of gravitating and radiant forces. Science, **50**, 29-82.

The displacement of the gravitating needle in its dependence on atmospheric temperatures. Nat. Acad. Sci., Proc., **5**, 547-550.

*1920*

An example of torsional viscous retrogression. Nat. Acad. Sci., Proc., **6**, 1-3.

On spiral nebulae. Science, **52**, 112-113.

L'interferometrie et les appareils interferentiel. Revue Generale des Sciences, **12**, 401-409.

Notes on a pneumatic method of measuring variations of the acceleration of gravity. Nat. Acad. Sci., Proc., **6**, 495-498.

Note on torsional measurement of variations of the acceleration of gravity by interference methods. Nat. Acad. Sci., Proc., **6**, 498-502.

Compression of a sound wave. Science, **52**, 586-588.

*1921*

Adjustable embouchure. Science, **53**, 47-48.

Acoustic pressure and acoustic dilatation. Science, **53**, 489-494.

An analogy between the theories of natural selection and electrolysis Science, **54**, 53.

Pneumatic paradox in acoustics. Science, 54, 155-156.
The energy content of the diapason Nat. Acad. Sci., Proc., 7, 47-50.
The open mercury manometer read by displacement interferometry. Nat. Acad. Sci., Proc., 7, 71-75.
The diffusion of air through water in the lapse of years. Nat. Acad. Sci., Proc, 7, 133-134.
Acoustic pressure distributions, chiefly in reservoirs and in pipes. Nat. Acad. Sci., Proc., 7, 207-213.
The U-tube absolute electrometer. Nat. Acad. Sci., Proc., 7, 242-244.
Displacement interferometry applied to acoustics and to gravitation. Carnegie Publications, 310, i-viii, 1-149.

*1922*

Experiments with the vacuum gravitation needle. Nat. Acad. Sci., Proc., 8, 13-15.
On summaries of recent advances in physics. Science, 55, 19-20.
Acoustic topography in a room. Science, 55, 321-326.
Periods and logarithmic decrement of the gravitation needle under high exhaustion. Nat. Acad. Sci., Proc., 8, 63-66.
Plane reflection of sound, as exhibited by the pinhole resonator. Nat. Acad. Sci., Proc., 8, 66-69.
Acoustic topography varying with the position of the organ pipe. Nat. Acad. Sci., Proc., 8, 96-100.
Cylindrical distribution of nodal strength around the pipe normal. Nat. Acad. Sci., Proc., 8, 119-123.
Positive and negative pinhole resonators. Nat. Acad. Sci., Proc., 8, 163-165.
Static deflections of the vacuum gravitation needle. Science, 56, 451-453.
Static deflection, logarithmic decrement and first semi-period of the vacuum gravitation needle. Nat. Acad. Sci., Proc., 8, 313-316.
On a comparison of the relative sensitiveness of telephones. Nat. Acad. Sci., Proc., 8, 326-327.
The equilibrium positions of the vacuum gravitation needle in 1921 and 1922. Nat. Acad. Sci., Proc., 8, 327-330.

*1923*

Glue bubbles. Science, 57, 151-153.
Gaseous viscosity measured by the interferometer U-tube. Nat. Acad. Sci., Proc., 9, 71-72.
Sparkless sparks. Science, 57, 420-421.
The displacement of the capillary electrometer, for progressive dilutions of the electrolyte. Nat. Acad. Sci., Proc., 9, 156-158.
Note on equations for tortuosity in Thomson and Tait's "Natural Philosophy." Science, 57, 562.
Interferometer experiments in acoustics and gravitation, II. Carnegie Publications, 310, Part II, I-VIII; 1-113.

The vibration of air in tubes capped at both ends. Nat. Acad. Sci., Proc., 9, 263-65.
The vibration of the air filament in quill tubes capped at both ends. Nat. Acad Sci., Proc., 9, 266-268.
Achromatic and superchromatic fringes with a calcite rhomb. Nat. Acad. Sci., Proc., 9, 373-376.
Vibration of the air filament in quill tubes. Single telephonic exciter. Nat. Acad. Sci., Proc., 9, 376-378.

*1924*

Vibration in spark-blown closed quill tubes. Electric oscillation. Nat. Acad. Sci., Proc., 10, 1-3.
Exhibit of telephonic excitation of acoustic pressure. Nat. Acad. Sci., Proc., 10, 96-99.
Density and diffusion of gases measured by displacement interferometry. Nat. Acad. Sci, Proc., 10, 153-155.
The hodograph of Newtonian hyperbolic reflection. Science, 59, 260.
Sensitive flames and apparent flame pressure. Science, 59, 137-138.
Density and diffusion measurement by displacement interferometry in extreme cases. Nat. Acad. Sci., Proc., 10, 349-351.
The diffusion of hydrogen into air, measured by the interferometer U-gauge. Nat. Acad. Sci., Proc., 10, 447-452.
Review of Pierre Curie, By Madame Curie. Translated by Charlotte and Vernon Kellog . . . Macmillan, New York, 1923. Amer. Hist. Rev., 29, 601.

*1925*

Review of Histoire de la nation francaise. Dirigee par Gabriel Hanotaux. Tom. XIV. Histoire des sciences en France, v. 1. Plon-Nourrit et Cie., Paris, 1924. Amer. Hist. Rev., 30, 589-91.
Pinhole probe measurements of the phase change of the telephonic end plates, acting on a closed cylindrical air column in longitudinal acoustic vibration. Nat. Acad. Sci., Proc., 11, 260-264.
The effect of commutation of impedances on the acoustic pressure, produced by paired telephonic systems. Nat. Acad. Sci., Proc., 11, 494-498.
Inductance treated acoustically by differential telephones. Nat. Acad. Sci., Proc., 11, 408-412.
The acoustic pressure in tubes capped by high resistance telephones vibrating in different phases. Nat. Acad. Sci., Proc., 11, 581-584.
Telephonic coupling of acoustic and electrical oscillations evidenced by the pinhole probe. Nat. Acad. Sci., Proc., 11, 728-732.
Interferometer experiments in acoustics and gravitation, III. Carnegie Publications, 310, Part III, i-ix; 1-165.

*1926*

Resonant acoustic and electric oscillations released by the relatively slow spring break. Nat. Acad. Sci., Proc., 12, 137-140.

Mutually counteracting pinhole probes. Nat Acad. Sci, Proc, 12, 223-227.
Acoustic pressures in case of soap bubbles. Nat. Acad. Sci., Proc., 12, 480-482.
Acoustic pressure promoted by coöperating quill tubes without pinholes. Nat. Acad. Sci., 12, 482-486.
Three phenomenal ages of cultural advance. Honor's Day address. Brown University Papers, IV.

*1927*

Pinhole probe record of the closed organ pipe. Nat. Acad. Sci., Proc, 13, 52-56.
Pinhole probe experiments with massive air columns. Nat. Acad. Sci., Proc., 13, 87-91.
Pinhole probe measurements with massive cylindrical air columns. Nat. Acad. Sci., Proc., 13, 223-227.
Linear elements of the electromagnetic pinhole graphs. Nat. Acad. Sci., Proc., 13, 313-315.
Reciprocating acoustic vibration on opposite sides of the pinhole in long quill tubes. Nat. Acad. Sci., Proc, 13, 579-583
Efficiency of pinhole probes. Science, 65, 329-331.
The electric wind pressure phenomenon. Science, 65, 448-450.
Mucronate electrode with micrometer. Nat. Acad. Sci., Proc., 13, 457-460.
Pressure phenomena of the mucronate anode. Nat. Acad. Sci., Proc., 13, 503-505.
Graphic treatment of Euler's equations. Science, 66, 114-115.
The convective spark discharge of the mucronate electrode. Science, 66, 358-359.
Acoustic experiments with the pinhole probe and the interferometer U-gauge. Carnegie Publications, 383, i-x, 1-158.
Change of convective to spark discharge. Science, 66, 658-659.

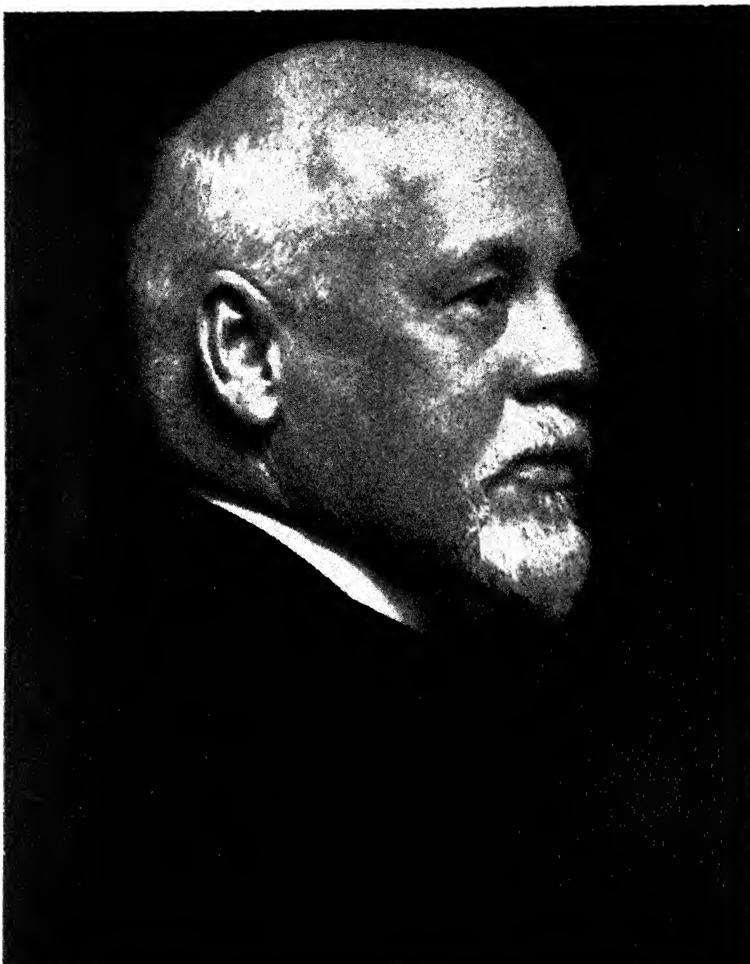
*1928*

Experiments with modified mucronate electrodes. Nat. Acad. Sci., Proc., 14, 188-191.
Anode and cathode sparks differentiated by the mucronate electrode. Nat. Acad. Sci., Proc., 14, 248-251.
Sparks of the induction coil between mucronate electrodes. Nat. Acad. Sci., Proc., 14, 465-469.
Little circle of reference. Science, 67, 530-531.
Telescopic observations of cathode and anode points. Science, 67, 248-249.
Reminiscences over fifty years. Columbia Alumni News, 31, 57.
The repulsion between electric currents and their induced eddy currents in parallel. Nat. Acad. Sci., Proc, 14, 542-544.

The displacement interferometry of barometric pressure. Nat. Acad. Sci., Proc., **14**, 641-645.
Diagrams relative to Hamilton's canonical equations. Science, **48**, 276-277.
Further experiments in microbarometry. Nat. Acad. Sci., Proc., **14**, 771-773.
The interferometer U-gauge with closed auxiliary reservoirs. Nat Acad. Sci., Proc., **14**, 855-857.
Chemical reaction in the interferometer U-gauge. Nat. Acad. Sci., Proc., **14**, 939-943.

*1929*

Adiabatic expansion in case of vanishing increments. Nat. Acad. Sci., Proc., **15**, 22-25.
Euler's tensor and Hamilton's cubic. Science, **69**, 248.
Adiabatic expansion in case of vanishing increments, II. Nat. Acad. Sci., Proc., **15**, 237-241.



William H. Welch

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—TENTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# WILLIAM HENRY WELCH

1850–1934

BY

SIMON FLEXNER

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1942

# WILLIAM HENRY WELCH *

## 1850–1934

BY SIMON FLEXNER

William Henry Welch was born April 8, 1850, into a family which for two generations had been country doctors in Connecticut. His grandfather, father, and his father's four brothers were all doctors, and William and four of his cousins were also to become doctors. Under such environmental influences, it was to be expected that William, an only son, would fall at once into his place in the family vocation, first assisting and later succeeding his father in practice in the charming village of Norfolk. But this did not happen, and when circumstances compelled William to study medicine it was only after he had failed in his ambition, on graduating from Yale College in 1870, to become a teacher of the classics. His predilection was for an academic life, not a life of practical affairs, and his chief passion at that time was for Greek. No tutorship being available for him, the young man, perhaps for the only time in his long life, was at loose ends. He taught school, for a year at Norwich, New York, while reflecting on the future before him. At the end of this year he joined his father and reluctantly took up the study of medicine. After a short period, he returned to New Haven, having wisely decided to study chemistry at the Sheffield Scientific School, for during his pupilship no experimental science was taught in the academic course at Yale.

William's forbears had studied medicine in the local medical schools—the peripatetic school at Pittsfield, Massachusetts, or the Yale Medical Institution, as the Yale school was then called—or they had become doctors merely through acting as apprentices to local practitioners. William alone of the family up to his time had had a liberal education preliminary to the study of medicine. In the autumn of 1872 he entered the College of Physicians and Surgeons, a leading school, in New York and graduated in the spring of 1875. The poverty of the medical

* Based on *William Henry Welch and the Heroic Age of American Medicine*, by Simon Flexner and James Thomas Flexner, New York, Viking Press, 1941.

curriculum can hardly be conceived by the medical student of today. The instruction was, with the exception of dissection in anatomy, almost wholly by didactic lectures. The courses were not graded, and the lectures were repeated in successive years. The possession of the doctor's degree carried with it the privilege to practice; state boards of examiners had not yet been instituted. Welch won an interneship in Bellevue Hospital which he completed in the spring of 1876, and there came under the influence of Francis Delafield, pathologist to the Hospital. Pathology exercised a strong attraction on him, so that the ardent young man was led to imagine a professional career for himself in that subject despite the fact that nowhere in America did there exist a chair of pathology from which a living could be extracted or a laboratory in which the subject could either be learned or taught. Nevertheless the fascination of such a career had taken firm hold of his mind and the vision was strengthened just then by the announcement of the opening of the Johns Hopkins University to take place in the autumn of 1876 in which was to be included a medical school with laboratories not only to train competent practitioners but also to further science.

Under the influence of this idea Welch sailed for Europe early in 1876, his destination being Strasbourg, where a strong new German university had been set up following the Franco-Prussian war of 1870. He spent a summer semester in the study of histology under Waldeyer, pathology under von Recklinghausen, and physiological chemistry under Hoppe-Seyler; and in order not to be impractical, Welch listened to von Leyden's lectures in medicine. His next move was to Leipzig, to the pathological laboratory of Ernst Wagner and especially the celebrated physiological laboratory of Carl Ludwig. Then Welch spent a semester at Breslau under the experimental pathologist Julius Cohnheim, with whom he carried out a piece of successful research on oedema of the lungs.

The early months of 1878 saw Welch again in New York. He sought immediately an opportunity to teach and work in pathology. Failing in his object at the College of Physicians and Surgeons, he turned next to Bellevue Hospital Medical

College, which gave him three small rooms and spent twenty-five dollars for tables and chairs. Half a dozen microscopes were obtained somehow and as many volunteer students put to work. The course was instantly successful. Very soon students from all three medical schools in the city joined the classes, and within half a year the College of Physicians and Surgeons felt obliged to offer a similar course. They tried to attract Welch, but he remained loyal to Bellevue and recommended T. Mitchell Prudden of New Haven, also a German student of pathology.

This, in brief, is the story of the founding of the first laboratory of pathology in America. The money returns were small. Welch turned to other employment to support himself: he made autopsies for physicians, examined and reported on specimens removed by surgeons, conducted quiz classes for hospital interneships, wrote for medical books, and engaged in private practice.

Welch's six years in New York brought him reputation for knowledge and skill, but no success in attaining his main object, which was to develop pathology along German lines. Then one day Dr. John S. Billings, whom Welch had met in Leipzig in 1877, the author of the Surgeon General's Catalogue, just then engaged in building the Johns Hopkins Hospital, walked into Welch's primitive laboratory, heard him lecture and watched him demonstrate, and talked to him about his future plans, inquiring what he would do if provided with adequate laboratory facilities. This was on March 1, 1884; on March 9 Billings was back in New York; on March 10 Welch was in Baltimore for a conference with President Gilman, who offered him the professorship of pathology at the Johns Hopkins University. Despite strong pressure made on Welch to remain in New York, he accepted the offer on March 31. His almost impossible dream of 1876 had come true.

In the middle seventies of the last century, when Welch studied in Germany, Robert Koch had not yet brought bacteriology into medical practice, and when he startled the world by the announcement of the cultivation of the tubercle bacillus in 1882 and the isolation of the cholera bacillus in 1883, Welch

was obliged to stand on the side-lines, as his small laboratory afforded no opportunity for the pursuit of bacteriology. His first move, therefore, after the Baltimore appointment, was to return to Germany for a year's study of bacteriology, first under a pupil of Koch's at Munich, then under Flugge at Göttingen, pupil of both von Pettenkofer and Koch, and finally under Koch himself.

The autumn of 1885 found Welch in Baltimore entering on his new duties. By good fortune he was given working space in Newell Martin's biological laboratory. The laboratory was actively engaged in teaching and research, and Welch found himself in the heart of a university and in a company of scholars. Welch was no scientific recluse, but a cultivated, companionable man, and he quickly established himself in the university circle. His happiness in the change from the arid years in New York is apparent in his letters.

In the six years that Welch spent in New York, he failed to bring a single piece of pathological research to a conclusion; in the next six or seven years ending with 1892-93 he brought to a successful end researches on Bright's disease of the kidneys, structure of white thrombi, hæmorrhagic infarction, pathology of fever, causation of hog cholera, pneumococcus and acute lobar pneumonia, bacteriology of diphtheria, and most important of all on the bacillus which bears his name—Clostridium or Bacillus welchii. This gas-producing bacillus which Welch discovered to be the cause of the presence of gas in the blood vessels and organs after death not attributable to post-mortem decomposition and erroneously mistaken for air, was to play a large rôle in pathology under a chapter to which Welch later gave the name of "pneumatopathology."

"The Pathological," as Welch's laboratory was called and in which he was to spend the first thirty years of his Baltimore period, was hastily completed on the Johns Hopkins Hospital grounds and occupied by him in 1886. It was a laboratory modelled after the German pattern only it was more inclusive than such laboratories were in Germany. Welch was to combine the pathological anatomy of Virchow with the experimental pathology of Cohnheim and the bacteriology of Koch probably

for the first time in the laboratory of one man. The opening of the Hospital was three years off and that of the Medical School seven years off. Hence courses were offered in pathology and bacteriology to graduates in medicine and facilities for research provided to more advanced students. The Pathological became a busy workshop and continued to be a center of teaching and research throughout Welch's professorship, which he resigned in 1916.

Almost from the beginning, however, Welch was drawn to the public platform in order first to expound the modern bacteriology and pathology, and then to promote the higher, or university, medical education. Welch had peculiar gifts which made him a graceful and persuasive speaker. He became, indeed, as the years passed, the teacher-at-large of scientific medicine throughout the nation. With the organization of the Hopkins Medical School, in which he took the leading part, he was still further diverted from strict laboratory duties, and with the founding of the many educational philanthropies and various welfare organizations for medical and social betterment during the twentieth century, he was called upon more and more for aid and guidance. All these extra-mural activities, many in the city of Baltimore, encroached on Welch's laboratory time; his personal influence there continued, but the main teaching and all the research were carried on by his associates and pupils.

Undoubtedly, Welch's greatest work was the upbuilding of the Hopkins Medical School, which exerted a strong influence in this country and even on medical education in Europe. The part which Welch played in developing the medical school extended over more than forty years. The first unit of the school to come into existence was the Johns Hopkins Hospital, which opened in 1889. At the outset a radical departure was made in the appointment of the major clinical staff, who became at the same time professors in the university. Hitherto medical schools in America were staffed from the local practitioners. The Hopkins called Osler in medicine, Halsted in surgery, and Kelly in gynecology, all from a distance. This was President Gilman's policy put into effect by Welch.

The four years between the opening of the hospital and the

launching of the medical school were anxious and strenuous ones. The school had already been too long delayed. It seems extraordinary, now that medicine has become so favored by philanthropy, that this long delay should have depended on the comparatively small endowment of $500,000. But it was not until medicine in America had entered on its course of modern scientific development that endowments became progressively more frequent and large. And in bringing about this fundamental change of direction Welch exerted a strong influence. The donors of the needed endowment at the Hopkins were a national group of women interested primarily in the higher education of women. In 1891 Welch had drawn up a plan of instruction in which he included, for admission to a medical school, preliminary training in biology, chemistry, and physics, and a reading knowledge of French and German. This standard was not to be adopted at once, but to be attained gradually. The women's committee seized on the plan and demanded its immediate execution, adding to it the possession of a college degree by the entrants and the admission of women on the same terms with men. All these conditions were reluctantly granted. Welch was made dean of the new school, the next step being the setting up of laboratories of anatomy, physiology, pharmacology and physiological chemistry staffed by trained teachers and investigators. The school got under way in 1893, and its classes grew in number with surprising rapidity. The country had proved more ready than had been foreseen to take so great a step forward in medical education.

About the end of the nineteenth century modern medical education was advancing rapidly and the output of scientific work had become considerable. The first scientific medical periodical—the *Journal of Experimental Medicine*—was issued in 1896 with Welch as editor. At the end of the century the Rockefeller Institute for Medical Research was founded with Welch as president of its Board of Scientific Directors. But progress in the clinical branches of medicine had lagged behind that in the laboratory branches. Welch now turned to the task of making the two branches more nearly equal. To this undertaking he devoted many of his energies for the first dozen years

of the new century, the result being the institution at the Hopkins in 1913-14 of university chairs, sometimes called full- or whole-time professorships, in the main clinical subjects.

Hygiene and public health had remained backward in the medical curriculum. Welch had become deeply impressed with their importance in Munich in 1884 while studying bacteriology there. He had spent a short time working in von Pettenkofer's hygienic institute. His efforts to develop hygiene on an adequate basis in the pathological laboratory had failed for lack of funds. But he had not ceased propagandizing for the subject. Then in 1916 the Rockefeller Foundation, in the furtherance of its public health work under the guidance of the International Health Board, founded the School of Hygiene and Public Health at the Johns Hopkins University with Welch as its first director.

Welch's last years were spent in the organization of the Institute of the History of Medicine in connection with the University's medical library bearing his name. The addition of medical history to the medical curriculum was also the realization of an early idea of Welch's. Speaking at Yale College in 1888, he had said that "nothing is more liberalizing and conducive to medical culture than to follow the evolution of medical knowledge." In 1927-28 he spent eighteen months in Europe buying books for the library and institute. The institute itself was formally opened in October, 1929. Welch remained its director until 1931, when he retired from active university duties. He had a broad conception of the study of the history of medicine which, he said, "requires information on all conditions of civilization of the particular period under consideration," and added that its real significance cannot be grasped "without knowing the state of contemporary knowledge of all important departments of science and philosophy."

* * * * * * *

Welch was elected to the National Academy of Sciences in 1895, was a member of the Council from 1902 to 1911, was elected president in succession to Ira Remsen for a six-year term in 1913. He resigned the presidency in 1917. It was in

Welch's presidency that the National Research Council was organized during the great war, and Welch served as member of the executive board of the Council from 1918 to 1933. On the entry of the United States into the war Welch became attached to the Surgeon General's office, advising on medical personnel, acting as liaison man between the laboratory men and the army, making inspection trips to the camps and advising on laboratory organization and epidemiological problems. After the war Welch journeyed to Cannes, France, and took a leading part in the founding of the League of Red Cross Societies which maintained a Bureau of Health in Geneva in connection with the League of Nations.

In 1906 Welch was made a trustee of the Carnegie Institution of Washington, and two years later chairman of the Executive Committee of the Institution.

Dr. Welch died on April 30, 1934, at the age of eighty-four.

## HONORARY SOCIETY MEMBERSHIPS

Académie de Médecine, Paris
Académie Royale de Médecine de Belgique
American Academy of Arts and Sciences
Berliner medizinische Gesellschaft
British Association for the Advancement of Science
British Medical Association
College of Physicians of Philadelphia
Comité International d'Histoire des Sciences
Deutsche medizinische Gesellschaft in New York
Deutsche Zentralkomitee zur Erforschung und Bekampfung der Krebskrankheit
Gesellschaft der Aerzte in Wien
Harveian Society of London
Hufelandische Gesellschaft, Berlin
International Anti-Tuberculosis Association
International Society for Microbiology
Istituto Storico Italiano dell'Arte Sanitaria
Kaiserlich Deutsche Akademia d. Naturforscher zu Halle ("Academia Leopoldina")
Pathological Society of Great Britain and Ireland
Pathological Society of London
Physiological Society (British)
Reale Accademia Medica di Roma
Royal College of Physicians, Edinburgh
Royal Medical and Chirurgical Society, London
Royal Sanitary Institute, London
Royal Society of Medicine, London
Schlesische Gesellschaft für Vaterländische Cultur
Società Medica Chirurgica di Bologna
Société Royale des Sciences Médicales et Naturelles de Bruxelles
Society of Medical Officers of Health, England
Wiener Gesellschaft für Mikrobiologie

## HONORARY DEGREES, DECORATIONS, AND MEDALS

1894: LL.D., Western Reserve University
M.D., University of Pennsylvania
1896: LL.D., Yale University
1900: LL.D., Harvard University
1903: LL.D., University of Toronto
1904: LL.D., Columbia University
1907: LL.D., Jefferson Medical College
1910: LL D., Princeton University
1911. Order of the Royal Crown, second class (Germany)

1915: LL.D., Washington University
Order of the Rising Sun, third class (Japan)
1916: LL.D., University of Chicago
1919: Gold medal awarded by the National Institute of Social Sciences in recognition of valuable services during the World War. Distinguished Service Medal and citation, United States Army.
1920: Order of the Cross of Mercy (Kingdom of Serbs, Croats, and Slovenes)
1922: Gold medal of the University of Vienna
1923: M D., University of Strasbourg
Sc.D., University of Cambridge
Legion of Honor—officer
1925: W. W. Gerhard gold medal awarded by the Pathological Society of Philadelphia
1926: Order of St. Olav, commander of the second class (Norway)
Diploma of the Distinguished Service Medal, United States Army
1927: Kober gold medal, with diploma, from Association of American Physicians
1929: D.Sc., Western Reserve University
1930: LL D., University of Southern California
Gold medal of the American Medical Association
Litt.D., University of Pennsylvania
LL.D., University of the State of New York
1931: Harben gold medal awarded for public health service by the Royal Institute of Public Health
1932: D.Sc., University of Maryland
D.Sc., New York University

## BIBLIOGRAPHY OF WILLIAM HENRY WELCH

### Key to Abbreviations

Albany Med. Ann.—Albany Medical Annals
Am. J. Med. Sc.—American Journal of Medical Science
Am. Med.—American Medicine
Am. Naturalist—American Naturalist
Am. Pub. Health Assn. Rep.—American Public Health Association Report
Arch. f. path. Anat. u. Physiol. u.f. klin. Med.—Archiv für pathologische anatomie und physiologie und klinische medizin
Boston Med. & Surg. J.—Boston Medical and Surgical Journal
Brit. Med. J.—British Medical Journal
Bull. Am. Acad. Med.—Bulletin, American Academy of Medicine
Bull. Harv. Med. Sch. Assn.—Bulletin, Harvard Medical School Association
Bull. Med. & Chir. Fac. Maryland—Bulletin, Medical and Chirurgical Faculty of the State of Maryland

Centralbl. f. d. med. Wissensch.—Zentralblatt fur die medizinischen wissenschaften
Johns Hopkins Hosp. Bull.—Johns Hopkins Hospital Bulletin
Johns Hopkins Univ. Cir.—Johns Hopkins University Circular
J. Alumni Assn. Coll. Phys. & Surg.—Journal, Alumni Association, College of Physicians and Surgeons, New York City
J. Am. Med. Assn—Journal, American Medical Association
J. Exp. Med.—Journal of Experimental Medicine
J. Physiol.—Journal of Physiology
Maryland Med. J.—Maryland Medical Journal
Med. News—Medical News
Nat. Assn. Study & Prev. Tuberc. Tr—National Association for the Study and Prevention of Tuberculosis, Transactions
New Eng. & Yale Rev.—New Englander and Yale Review
Papers & Addresses—Papers and Addresses by William Henry Welch, edited by Walter C. Burket, 3 vols., Baltimore, 1920.
Pop. Health Mag.—Popular Health Magazine
Proc. Nat. Confer. Char.—Proceedings, National Conference of Charities and Correction
Proc Path. Soc. Phila.—Proceedings, Pathological Society of Philadelphia
Southern Med. J.—Southern Medical Journal
Tr. Am. Surg. Assn.—Transactions, American Surgical Association
Tr. Assn. Am. Physn.—Transactions, Association of American Physicians
Tr. Cong. Am. Physn. & Surg.—Transactions, Congress of American Physicians and Surgeons
Tr. Med. & Chir. Fac. Maryland—Transactions, Medical and Chirurgical Faculty of the State of Maryland
Tr. Path. Soc. Phila.—Transactions, Pathological Society of Philadelphia
William Pepper Lab. Clin. Med. (Proc.)—William Pepper Laboratory of Clinical Medicine (Proceedings)
Yale Med. J.—Yale Medical Journal

*1878*

Zur Pathologie des Lungenödems. Arch. f. path. Anat. u. Physiol. u. f. klin. Med., *72*, 375. Papers & Addresses, *1*, 3.

*1884*

Zur Histiophysik der roten Blutkörperchen. (With S. J. Meltzer.) Centralbl. f. d. med. Wissensch., *22*, 721.
The behaviour of the red blood-corpuscles when shaken with indifferent substances. (With S. J. Meltzer.) J. Physiol. (London, *5*, 255.) Papers & Addresses, *1*, 42.

*1886*

On some of the humane aspects of medical science. Johns Hopkins Univ. Circ., *5*, 101. Papers & Addresses, *3*, 3.
An experimental study of glomerulonephritis. Tr. Assn. Am. Physn., *1*, 171. Papers & Addresses, *1*, 293.

*1887*

Modes of infection. Tr. Med. & Chir. Fac. Maryland, 1887, 67. Papers & Addresses, *1*, 549.

The structure of white thrombi. Tr. Path. Soc. Phila., *13*, 281. Papers & Addresses, *1*, 47.

Haemorrhagic infarction. Tr. Assn. Am. Physn., *2*, 121. Papers & Addresses, *1*, 66.

Experimental study of haemorrhagic infarction of the small intestine in the dog. (With Franklin P. Mall.) Papers & Addresses, *1*, 77. (Written in 1887, but not published until 1920.)

*1888*

The Cartwright Lectures. On the general pathology of fever. Boston Med. and Surg. J., *118*, 333; 361; 413 Papers & Addresses, *1*, 302.

Some of the advantages of the union of medical school and university. New Eng. & Yale Rev., *13*, 145. Papers & Addresses, *3*, 26.

*1889*

Hydrophobia. Tr. Med. & Chir. Fac. Maryland, 1889, 162. Papers & Addresses, *1*, 395.

Considerations concerning some external sources of infection in their bearing on preventive medicine. Med. News, *55*, 29. Papers & Addresses, *1*, 567.

Preliminary report of investigations concerning the causation of hog cholera. Johns Hopkins Hosp. Bull., *1*, 9. Papers & Addresses, *2*, 79.

Pathology in its relations to general biology. Johns Hopkins Hosp. Bull., *1*, 25. Papers & Addresses, *3*, 191.

*1891*

The causation of diphtheria. Tr. Med. & Chir. Fac. Maryland, 1891, 242. Papers & Addresses, *2*, 197.

The etiology of diphtheria. (With Alexander C. Abbott ) Johns Hopkins Hosp. Bull., *2*, 25. Papers & Addresses, *2*, 181.

The histological changes in experimental diphtheria. (With Simon Flexner.) Johns Hopkins Hosp. Bull., *2*, 107. Papers & Addresses, *2*, 218.

Additional note concerning the intravenous inoculation of *Bacillus typhi abdominalis*. Johns Hopkins Hosp. Bull., *2*, 121. Papers & Addresses, *2*, 332.

Conditions underlying the infection of wounds . . . Am. J. Med. Sc., *102*, 439. Papers & Addresses, *2*, 392.

Some considerations concerning antiseptic surgery. Maryland Med. J., *26*, 45. Papers & Addresses, *2*, 419.

*Bacillus coli communis;* the conditions of its invasion of the human body, and its pathogenic properties. Med. News, *59*, 669. Papers & Addresses, *2*, 328.

*1892*

*Micrococcus lanceolatus*, with especial reference to the etiology of acute lobar pneumonia. Johns Hopkins Hosp. Bull., *3*, 125. Papers & Addresses, *2*, 146.

The etiology of acute lobar pneumonia, considered from a bacteriological point of view. Tr. Med. & Chir. Fac. Maryland, 1892, 1. Papers & Addresses, *2*, 124.

The advancement of medical education (N.T.) Bull. Harv. Med. Sch. Assn., 1892, 55. Papers & Addresses, *3*, 41.

The histological lesions produced by the toxalbumen of diphtheria. (With Simon Flexner.) Johns Hopkins Hosp. Bull., *3*, 17. Papers & Addresses, *2*, 225.

A gas-producing bacillus (*Bacillus aerogenes capsulatus*, nov. spec.), capable of rapid development in the blood-vessels after death. (With G. H. F. Nuttall.) Johns Hopkins Hosp. Bull., *3*, 81. Papers & Addresses, *2*, 539.

*1893*

Sanitation in relation to the poor. Charities Review 1893, February. Papers & Addresses, *1*, 588.

Asiatic cholera in its relations to sanitary reforms. Pop. Health Mag., *1*, 6. Papers & Addresses, *1*, 599.

The Johns Hopkins Medical School. Baltimore, 1893, 6 p., 8°. Papers & Addresses, *3*, 9.

*1894*

Remarks on hog cholera and swine plague. (With A. W. Clement.) Philadelphia, 1894, 37 p., 8°. Papers & Addresses, *2*, 86.

Higher medical education and the need of its endowment. Med. News, *65*, 63. Papers & Addresses, *3*, 46.

Bacteriological investigations of diphtheria in the United States. Am. J. Med. Sc., *108*, 427. Papers & Addresses, *2*, 229.

*1895*

The treatment of diphtheria by antitoxin. Johns Hopkins Hosp. Bull., *6*, 97. Papers & Addresses, *2*, 265.

What shall be the mode of procedure in determining the pathogenesis of bacteria found in water? Am. Pub. Health Assn. Rep., *20*, 502. Papers & Addresses, *2*, 645.

The evolution of modern scientific laboratories. William Pepper Lab. Clin. Med. (Proc.), 1895, No. 2, 17. Papers & Addresses, *3*, 200.

*1896*

The influence of anaesthesia upon medical science. Boston Med. & Surg. J., *135*, 401. Papers & Addresses, *3*, 215.

Intestinal and hepatic actinomycosis, associated with leukemia. (N.T.) Tr. Assn. Am. Physn., *11*, 328. Papers & Addresses, *1*, 541.

Observations concerning *Bacillus aerogenes capsulatus* (With Simon Flexner.) J. Exp. Med., *1*, 5. Papers & Addresses, *2*, 564.

*1897*

Adaptation in pathological processes. Tr. Cong. Am. Physn. & Surg., *4*, 284. Papers & Addresses, *1*, 370.

Principles underlying the serum diagnosis of typhoid fever and the methods of its applications. J. Am. Med. Assn, *29*, 301. Papers & Addresses, *2*, 336.

Biology and medicine. Am. Naturalist, *31*, 755. Papers & Addresses, *3*, 234.

The relation of sewage disposal to public health. Maryland Med. J, *38*, 199. Papers & Addresses, *1*, 607.

*1898*

Objections to the antivivisection bill now before the Senate of the United States (S. 1063). J. Am. Med. Assn., *30*, 285. Papers & Addresses, *3*, 455.

*1899*

Thrombosis and embolism. In: System of Medicine (Allbutt), London, 1899, *7*, 155. Also, System of Medicine (Allbutt & Rolleston), London, 1909, *6*, 691. Papers & Addresses, *1*, 110.

Relations of laboratories to public health. Am. Pub. Health Assn. Rep, *25*, 460. Papers & Addresses, *1*, 615.

*1900*

The material needs of medical education. J. Alumni Assn. Coll Physn. & Surg. (Baltimore), *2*, 97. Papers & Addresses, *3*, 63.

Venous thrombosis in cardiac disease. Tr. Assn. Am. Physn., *15*, 441. Papers & Addresses, *1*, 259.

Argument against Senate bill 34, fifty-sixth Congress, first session, generally known as the "Antivivisection Bill." J. Am. Med. Assn., *34*, 1242. Papers & Addresses, *3*, 469.

Morbid conditions caused by *Bacillus aerogenes capsulatus*. Boston Med. & Surg. J., *143*, 73. Papers & Addresses, *2*, 599.

*1901*

Training for and careers in clinical medicine. (N.T.) Presidential address. Tr. Assn. Am. Physn., *16*, p. xvi. Papers & Addresses, *3*, 273.

Laboratory methods of teaching. Tr. Am. Surg. Assn., *19*, 219. Papers & Addresses, *3*, 71.

The relation of Yale to medicine. Yale Med. J., *8*, 127. Papers & Addresses, *3*, 243.

*1902*

The Huxley Lecture. On recent studies of immunity with special reference to their bearing on pathology. Brit. Med. J., 1902, *2*, 1105. Papers & Addresses, *2*, 359.

*1903*

The pathological effects of alcohol. In: Physiological aspects of the liquor problem, Boston, 1903, *2*, 349. Papers & Addresses, *1*, 413.

*1904*

Theory of pulmonary oedema. (A letter to S. J. Meltzer.) Am. Med., *8*, 195 Papers & Addresses, *1*, 36.

*1906*

The benefits of the endowment of medical research. Studies from the Rockefeller Inst. for Med. Research, *6*, 26. Papers & Addresses, *3*, 74.

The unity of the medical sciences. Boston Med. & Surg. J., *155*, 367. Papers & Addresses, *3*, 305.

Position of natural science in education. (N.T.) Science, *25*, 52. Papers & Addresses, *3*, 83.

*1907*

The relation of the hospital to medical education and research. J. Am. Med. Assn., *49*, 531. Papers & Addresses, *3*, 132.

Some of the conditions which have influenced the development of American medicine, especially during the last century. Columbia Univ. Quarterly Supplement, *10*, 39. Papers & Addresses, *3*, 288.

Chronic peritonitis with complete obstruction, caused by numerous constrictions of a previously undescribed character, throughout the intestine. J Am. Med. Assn., *51*, 719. Papers & Addresses, *1*, 449.

*1908*

Medicine and the university. J. Am. Med. Assn., *50*, 1. Papers & Addresses, *3*, 89.

The interdependence of medicine and other sciences of nature. Science, *27*, 49. Papers & Addresses, *3*, 315.

What may be expected from more effective application of preventive measures against tuberculosis. Albany Med. Ann., *29*, 256. Papers & Addresses, *1*, 632.

A consideration of the introduction of surgical anaesthesia. Boston Med. & Surg. J., *159*, 599. Papers & Addresses, *3*, 221.

*1910*

The medical curriculum. Bull. Am. Acad. Med., *11*, 720. Papers & Addresses, *3*, 104.

Fields of usefulness of the American Medical Association. J. Am. Med. Assn., *54*, 2011. Papers & Addresses, *3*, 334.

*1911*

The significance of the great frequency of tuberculous infection in early life for prevention of the disease. Nat. Assn. Study & Prev Tuberc. Tr., *7*, 17. Papers & Addresses, *1*, 440.

*1912*

Advantages to a charitable hospital of affiliation with a university medical school. Survey, *27*, 1766. Papers & Addresses, *3*, 146

The hospital in relation to medical science. J. Am. Med. Assn., *59*, 1667. Papers & Addresses, *3*, 142

*1914*

Present position of medical education, its development and great needs for the future. (N.T.) Lancet-Clinic, *111*, 104. Papers & Addresses, *3*, 111.

Twenty-fifth anniversary of The Johns Hopkins Hospital, 1889-1914. Johns Hopkins Hosp. Bull., *25*, 363. Papers & Addresses, *3*, 20.

Address at the formal opening of the Peter Bent Brigham Hospital Peter Bent Brigham Hosp. Pamphlet, Boston, 1914, 8. Papers & Addresses, *3*, 153.

*1915*

The times of Vesalius. Contributions of Vesalius other than anatomical. Johns Hopkins Hosp. Bull., *26*, 118. Papers & Addresses, *3*, 428.

The duties of a hospital to the public health. Proc. Nat. Confer Char., Baltimore, 1915, 209. Papers & Addresses, *1*, 621.

Spirit of experimental science in education and opportunities for scientific medicine and service in China. Papers & Addresses, *3*, 174.

*1916*

Institute of hygiene. Rockefeller Foundation Ann. Rep., 1916, 415. Papers & Addresses, *1*, 660.

Medicine in the Orient. Bull. Med. & Chir. Fac. Maryland, *8*, 196. Papers & Addresses, *3*, 178.

Medical education in the United States. Harvey Lectures, 1915-16, 366. Papers & Addresses, *3*, 119.

The School of Hygiene and Public Health at the Johns Hopkins University. Science, *44*, 302. Papers & Addresses, *1*, 669.

*1919*

Influence of English medicine upon American medicine in its formative period. Contrib. Med. & Biol. Research, dedicated to Sir William Osler . . . by his pupils and co-workers, New York, 1919, 811. Papers & Addresses, *3*, 445.

*1921*

The advancement of medicine and its contribution to human welfare. In: Addresses & Papers at the Dedication Ceremonies and Medical Conference, Peking Union Medical College, 1921, Peking, 1922, 148.

Pathological problems in the Orient. *Ibid.*, p. 377.
Pneumonic plague *Ibid.*, p. 359.

*1924*

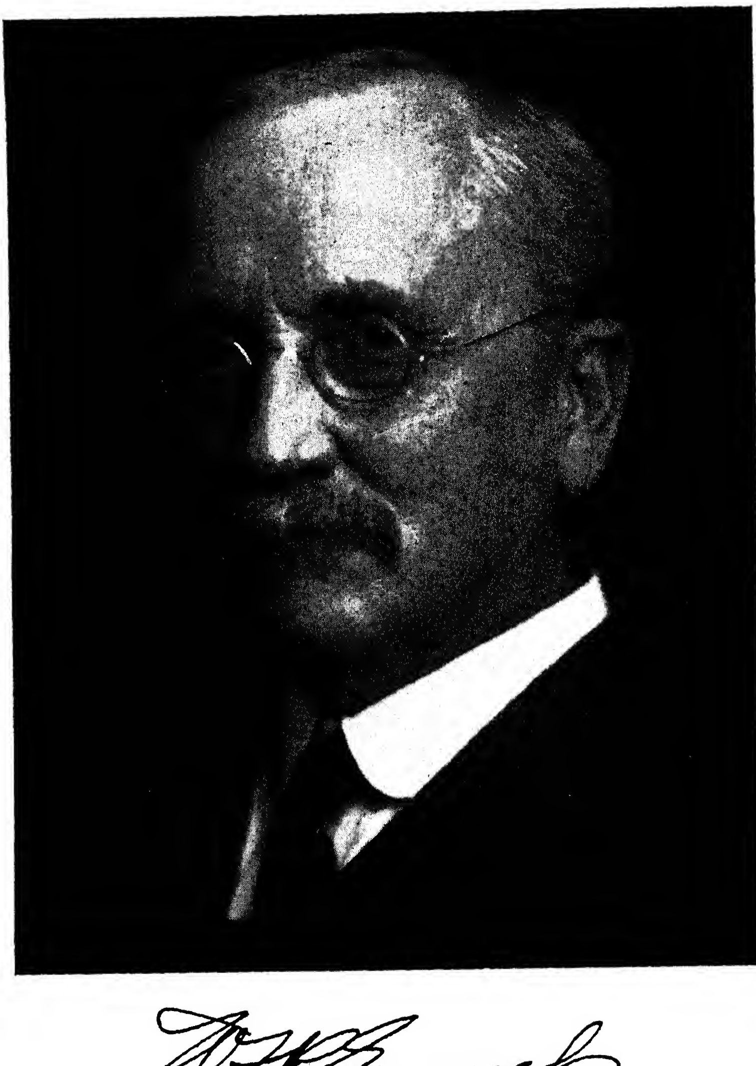
Public health in theory and practice: an historical review; William Thompson Sedgwick memorial lecture, January 25, 1924. Yale University Press, 1925. 51 p.

*1925*

W. W. Gerhard and differentiation of typhus and typhoid fever. Proc. Path. Soc. Phila., *28*, 42.

*1931*

Changing view-points in medical education Southern Med. J., *24*, 1121.
Distinguished physicians who have graduated from West Nottingham Academy. Tr. Med. & Chir. Fac. Maryland, 1931, 148.



NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—ELEVENTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# WILLIAM LE ROY EMMET

1859–1941

BY

WILLIS R. WHITNEY

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1942

# WILLIAM LE ROY EMMET

## 1859–1941

BY WILLIS R. WHITNEY

In attempting this biography, I am actuated by two separate motives. First; a wish to satisfy the request of the Academy, and then the sincere hope that I may do some good to young men who may be influenced by Emmet's precepts and example, in the problems of ever-bettered living.

Anyone who has read Dr. Emmet's "Autobiography of an Engineer" will wonder why I do more than abstract parts of that book, where everything is plainly and forcefully written, and so interestingly condensed. There the real character is exposed.

But I look at Emmet's life as more instructive to the youth, than is succinctly explained in the book. The book is more an unusual practice than a preachment, and the reader may be diverted by some oddities. So, meditation may be in order. The world's views on how best to live, are not especially tangible or in agreement; and Emmet had a way that proved good. People everywhere are apt to think pretty much as they are early advised to do, and they often do, without strenuous effort, about what the average does. This in itself may be an efficiency-agent for general survival. It may preserve, but it does not advance civilization. It is even questioned by modern metaphysicians, whether real advance is desirable or continuously possible, and whether we are any better off in our infinite artificial complexities, than the monkeys in the palm-trees, who by merely extending their arms, get food and pleasant drink, while enjoying both in the protecting shade.

Emmet early acquired a different and more efferent view. In his early youth he had stubbornly struggled to improve his own opportunities, while authorized teachers (of far less persistence) "marked him down." Finally he had experimentally proved that he did not have to remain submerged. He always felt that anything could be improved if it were rightly attacked, even Emmet. It was that idea, rather than any accumulated

data of pure science, which later determined his admitted success. He always worked hard, even into his "80's". To some friends, his ways seemed the most difficult. No one would have called him a patient man, but persistence was almost personified in him. He continually battled against himself and against deficiency in other men and materials. He would weepingly condemn himself forever, because of some slip of a golf-stick but he would loan money to almost anyone without critical feelings.

Mr. Emmet was what is properly called a research-engineer and one of rare ability, inquisitiveness and dynamic force. The engineer is usually a man who, knowing the physics of matter, and strengths of materials, together with prospective and current costs, constructs through the help of men and machines, structures such as will endure under the probable load of use and some abuse. But engineering continually changes in our days, and the manufacture of the newer products is due to the faith and works of the productive engineer. Those who, like Emmet, are never satisfied to stop improving designs, account for our new and better buildings, bridges, motors, tanks, locomotives, aeroplanes, etc. Thus the good engineer advances the "calling" itself by conservative but fearless use of new discoveries. Emmet was a research-engineer because he so often undertook difficult researches in order to help supply the data needed by engineers in order to design newly.

If it were not a hallowed custom, I might have declined writing this article, but a fairly close association with Mr. Emmet for about forty years decided it. The American Society of Mechanical Engineers published his autobiography in 1940. In that book of 225 pages one may read a very detailed story of his life. It is an intimate and revealing picture of a man who was always trying to serve his race. There too one sees those remarkable abnormalities of mind and hand, persistence, egotism, friendly good-will, non-conformity, non-complaisance, and kindness, which were outstanding parts of his personality. He was certainly "different." He knew it and gloried in it. He even wanted youth to understand and benefit by it.

He was born July 10th, 1859, on Travers Island, near New York, and was one of ten children. His great-grandfather was

Thomas Addis Emmet. Thomas was the first of the family to migrate to America. Thomas was the elder brother of the heroic leader of the ill-fated Association of the United Irishmen, Robert Emmet. Robert was executed after the failure of his Dublin plot (1803) and his memory remains forever green in the hearts of the Irish. Thomas being banished, came to this country, where he became very successful and honored. He was at one time Attorney General of New York State. His son in turn (also named Robert) born in Dublin in 1790, "a man of very fine physique, temperate, clean and of excellent understanding," was William Le Roy's grandfather, and his father was William Jenkins Emmet. Thus grand memories and some genetic forces of fighting spirit and loving disposition were evidently dominant in his heredity. Of his mother, whose maiden name was Julia Colt Pierson, he wrote: "I believe that a good mother is a wonderful asset, but in my case I think it can be truly said that my advantages in that respect were unusual. My mother was beautiful, noble and of extraordinary intelligence and exalted ideals."

He graduated from the United States Naval Academy in 1881 and was later a cadet on a long voyage of the U. S. S. Essex. This was a sailing vessel with a steam auxiliary which gave much trouble. Salt water was used in the boilers and these had to be frequently "blown-down" to keep the salt content below a certain limit. Such experiences evidently gave him much desirable knowledge of the practical improvements to be made in the propulsion of Naval vessels.

Before selecting items of his success, let me give my own picture of what I saw in his mind during four decades of contacts. He always looked upon himself as "a hound for detail" but highly forgetful and most absentminded. Truth is very exacting; and close contact with it led him to make many experiments where others may have delved less carefully. He thought that individual mental power, originality and directive ability were about as lacking in the "good scholar" as in the poorer one and he dubbed himself a poor one. The inquisitiveness of perpetual youth, however often it may be discouraged by those "Who ought to know better," was his asset. Admitted ignorance

is a firm foundation for the buildings of natural curiosity. For that reason he never hesitated literally "to stick his neck out," whether it was about the structure of the moon, the social theories of President Wilson, the weakness of other men, his own handicap at golf, the economy of steam generation, some vagary of ice-curling, salmon fishing or of moose hunting. He was mentally omnivorous. He had no fear of ridicule. He frequently wrote such self-evident truths as: "I think that my ideas are valuable." But I am sure that he visualized in the possible developments, the addition to his knowledge which came through the contributions of ideas of others who in various ways felt forced to correct him if possible. It was doubtless for that end that he knowingly and persistently "put out his feelers." Having no false mental reserve, he sensed the great values of verbal contacts. At one time he could write: "The men with whom I came in contact did not understand me at all and did not see my possibilities." Again, "I gave the chief engineer the benefit of my opinion but if he had known that he was talking to a great engineer, he might" etc., and again "many good specialists are not experimenters. Their tendency is to think that their science is sufficient for all needs, which is always a very erroneous idea." . . . "In engineering, the leader must know the detail, and force others to it." . . . "All of which goes to show that the teacher is not always right." . . . "It is better to seek arts and facts rather than other people's opinions."

But he always acted as though he knew that nature held in front of him an endless number of interesting and productive new laws, materials and technical novelties, and that even in our day, they were only to be approached slowly and under considerable difficulty.

It would be a serious mistake to overlook the all-roundness of Mr. Emmet while trying to do justice to his engineering powers. I know of no one who so intelligently conjoined vocation, vacation and avocation. In his early days in Schenectady he was constructively active in introducing there such outdoor sports as skiing, skate-sailing, ice sailing and also always contributed some related novelty such as a new harness for skiis or a bow-shape front edge for a skate sail. Many friends

learned about his skill as a fisherman by being notified at the Mohawk Club that a fresh salmon for him was in the ice box sent from some remote river by Mr. Emmet.

With our modern engines, motors, movies, radios, x-rays, television, cyclotrons and electron-microscopes, he saw how much men learn from healthy curiosity. He saw that man never need be satisfied, though he could oppose dissatisfaction. "Unsatisfied" was his motto. He clearly and hugely enjoyed difficult engineering. He did more than his part in releasing power of new service from nature's boundless box of still unrecognized servants. That is a sort of liberation which may go on forever (if history from the Stone Age is any criterion). And to quote a recent address: "It will be impossible to put back into their bottles the genii which have been released."

As an illustration of possible advantage of the biographer over the autobiographer, I shall emphasize from Emmet's life some of the points in modern engineering which young ambitious men should know. For example: after leaving the Navy, Emmet tried, more or less unsuccessfully, several different ways of making his living. One of these was as helper in the arc lamp factory of the United States Illuminating Company in New York. This was in '86 when electricity was less understood, and those in the lamp industry knew so little about it that Emmet, because of his schooling with motors and generators at the Naval Academy, was able to acquire and use much practical electrical knowledge. Here was a turning point in his self-confidence. He had little self-confidence at the time, "although that has been my strong suit in later life."

Those who knew him intimately saw that his confidence was his winning card. But I want to point out that, with such isolated individuals (even most inventors), there is always present the danger of failure before their promising undertakings can be completed. This is part of the explanation for our large long-lived American-type manufacturing organizations. Here Emmet was made successful. Here experts of different lines—from conceiving, experimenting, engineering, financing; through manufacturing and profitably selling,—combine and cooperate for success. Emmet's life well illustrates this point.

In sharp and sad contrast to it was the life of his first employer, the fervid, lone-eagle, entrepreneur Frank Sprague. In our present large industrial undertakings, it is not enough to have conservative engineering, or even that of bolder type. Support is needed. After a long life of arduous electrical promotion and engineering, Frank Sprague died impoverished; Emmet, wealthy. They seemed quite alike in their boundless energy, enthusiasm, engineering strength and personal boldness. Both were trained in our Naval Academy, though in different classes. Both were outstanding members of the Naval Consulting Board of 1917. Of him Emmet wrote: "There are few men in the electrical industry who have been more uniformly right than Frank Sprague, and I always had a great admiration for his intelligence, originality and courage."

In his formative years Emmet had designed, manufactured and sold some of his brain-children. But his life afterwards showed that he could conceive and design much greater contributions to electrical development than almost any individual could both design and produce. When he came to Schenectady (he says) "It was a very important move." He came into contact with many business men and also those skilled in arts, together with their machines. He thus rapidly extended his mental scope and realized "That with the facilities in men and machinery now available, I ought to be able to do good work." This conclusion well fits into the picture of organization where each of many different ambitious specialists devotes his personal abilities to working with others. Such is a reason for modern large industrial corporations.

Emmet wrote later: "I have never had any idea of leaving Schenectady, although I have had very attractive offers of other work. I have had no desire for promotion, have avoided executive duties as much as possible, although I have demonstrated that I can handle them ably, and my position has been very much what I chose to make it."

Together with this, ought to be taken the facts that among other activities, such as planning and selling the largest steam turbine, he also designed the radically novel electric propulsion apparatus for ships and personally gave information to prospec-

tive purchasers. Our Navy vessels are now in many cases driven by his propelling devices.

Thus Emmet was not seriously restricted in his efforts, and on the other hand he was relieved of duties gladly shouldered by men particularly trained for them, who took pleasure all their lives in helping his dreams come true.

It was characteristic of Mr. Emmet not to harbor his ideas, but to launch and sail them forth in any sea, where they had to sink or float, "on their own." I admired that character. At one place in his book, he criticised President Wilson for thinking and saying that employees of large corporations were to be pitied because forced to do the bidding of their superiors, etc. Emmet wrote: "in this he is almost completely wrong, because he, like most political critics of industry, had not had opportunities of knowing its complicated conditions. The idea that he (the employee) is less independent than the man employed by smaller concerns, is utterly fallacious."

He vigorously defends "largeness" with such words as "wrongdoing by large concerns is for many reasons difficult and unsafe." By that he called attention to the fact that men usually pull well together when the integrity of all is evident to each. And it becomes dangerous in such a group, to suggest ways unethical or low-aimed. When men are "in conference" they usually put forward only their best thoughts. A low-down thinker is apt to be excluded.

Emmet's pioneering in the problems of steam turbine is one of several cases in which a radical engineering experimenter was given his grand opportunity by adequate support. At the time, it was a burning question whether the principle of the steam turbine could be made to compete with the existing reciprocating engines which had had such long and continued improvement. Curtis in America and Parsons in England had not proved the technical advantages in cases of large power turbines; though it seemed promising on paper. Mechanical developments and suitable materials had not "arrived." The facts at this stage forced engineers to question the technical outlook, even after three years of intense local development. At this point Emmet met Curtis and became convinced of the

basic idea that continuous rotation of the pressure-surfaces had such great advantage over the stop and restart of reciprocating pistons, that it must ultimately succeed. Efficiency of power production from fuel, which was ever afterwards Emmet's life-aim, had still not proved so high for turbines as for standard type steam engines. Emmet, though claiming to be no thermodynamist, felt so certain of the turbine-future that he at once accepted the difficult job of proving its value. Through the cooperation of many men, minds and machines, success followed the bold venture. After five years of painful effort and frequent disappointment he could then write: "We developed an enormous industry and put practically every engine builder in the country out of business so far as the driving of electrical apparatus was concerned." Injuring others was never his aim, but almost anyone can appreciate the great advantage to electrical manufacturers of controlling and making their own complete power plants.

A typical Emmet act is recorded by him in his relations with Mr. Junggren, who was his manufacturing agent for all the detailed work. He had great faith in Junggren, but because Emmet was an experimenter, things did not always go smoothly, and he had "many long contests with him." But when Junggren received a flattering offer of work elsewhere, Emmet reports the outcome as follows (which shows the honest Irish wit so dominant in him): "I told Mr. Rice (Chief Engineer) that I was spending too much of my time contending with him and I could get along better without him. He asked me what he should do about letting him go, and I told him to pay his price and *hold* him, an action of which I have always been glad." They worked together happily for many years afterward.

Of Curtis, whose ideas were made practical by Emmet, he wrote: "When he was given the Rumford Medal at Harvard, I was in the audience and he did not know it. He spoke more of my doings than of his own and in fact did not do himself justice at all." (Emmet-like.)

Sensitive to the needs of coming engineers, Emmet, when he had learned of the possibilities and advantages of the more modern alternating current over the predominant direct cur-

rent, proceeded to write a book on the subject. This was a highly appreciated step in education by a busy man.

His long life was filled with attempts to devise improvements in electrical fields. His introduction of mica tape winding, together with forced air-circulation for more effective cooling of large apparatus, was called-for by the rapid advance in the then new aluminum industry, where the largest then known alternating currents had to be changed into direct current. He was engaged not alone in such work of detail. It is worthy of note that he wrote as follows: "The more a man originates and tends to depart from the beaten path, the more he has to exert himself in selling his product and in this respect I have had to be very active." But he also wrote: "While I have given the impression that various things were my doing, there were few things that I did in which others did not have a hand and many that I could not have done without able help." Too true! But he was a great catalyzer.

Nowadays when the existing interconnected alternating systems everywhere criss-cross the country, and that too with such frequency-control that electric clocks used thereon keep perfect time everywhere, we are apt to forget that in Emmet's day the problems of working alternators in parallel (without "hunting"), had still to be solved. It is an interesting part of his work which helped thus to extend the applications of alternating currents.

In many other problems of electrical engineering, he either brought about the advance by his own effort and vigorous experimental work or by instigating and encouraging others. Among such things is the long-used "varnished cambric" insulation, which soon displaced other materials like shellac. His varnish was glazed into the cambric by heat. This contributed to his aim of a thoroughly waterproof insulation. In the case of railway motors operating under ice-and-snow conditions of winter, this was of supreme importance. His work on oil switches is another case of that kind where close knowledge of details was absolutely necessary for his success. As the demands continually increased for higher and higher power, there was a natural extension of these switching and circuit-breaking

devices. Here again his practical experience supplied him with what was needed.

I recall with interest that when he laid the foundations for the engineering of mercury boilers, Emmet went at once into the very simplest but fundamental experiments. Many of these he insisted on performing himself and all of them he had to witness. This gave him the "feel" of the physics of the problem. He began by using for a research-"boiler" a straight glass test-tube of about two inches diameter and six feet long. It held more mercury than we had ever seen before. Mercury boiled in this tube with troublesome "bumping" at atmospheric pressure. But this showed him at once how to go about improving boiler-tubes. The ratio of heating surface to volume of mercury had been altogether too small. He then tried a double test-tube, still of glass, one tube being suspended (submerged) within the mercury in a slightly larger tube. Here the liquid was confined and boiled in the annular space between the walls. A study was then made of the preferred space-dimensions. His aim was to use less mercury and yet give it as great surface-contact with the heat as possible, while providing also for the escape of the vapors.

This is not the place for recording his experimental troubles, but the forceful way he worked and his insistence on personal close contact with every relevant detail should be illustrated.

The experiments with glass tubes led to the design of the first steel boilers put into actual service. These were the so-called "porcupine-types," and involved the double test-tube design. Thousands of these steel tubes (welded shut at the bottom), were also at the tops welded into the large vapor-dome. This welding in those early days of a now highly developed art, seemed, and was, almost impossible. Most of the trouble (and there was much of it) was due to leaks of precious mercury through defects in welding. It was almost too early in the history of electric welding or gas welding, but this again illustrates the difficulties which Emmet like other innovators was bound to meet. He knew that such combinations of novelties as mercury in boiler-tubes and new welding processes were capable of working exponentially, just as men with individuality

cooperate to an extent beyond the simple sum of their separate abilities. I think it was this peculiar knowledge on the part of Mr. Emmet which he saw as his greatest asset. It is not generally understood.

The desirable position of safety in a research engineer's work, whether it shall be "safety first," or, for future developments, some modification like "safety last," is more clearly expressed in a paper he wrote in 1904.

"Many engineers may consider the part of wisdom is to adopt only apparatus, the usefulness and reliability of which has been well established by experience. There are many cases, however, in which such reasoning cannot be wisely adopted, and among these the case of steam turbines is conspicuous." He was not guessing nor wishfully thinking, but basing this conclusion upon facts of steam characteristics. He also knew that the same forces of improvement as had led steam-engine development to continued higher efficiencies, would certainly contribute to the newly attempted but obviously promising turbine fields. There should be no end to improvements in either field, but the conservative estimated possibilities of the fresher field influenced his views. This was well warranted by the new facts which his efforts later brought to light. Improvement continued for a quarter-century. It shows no sign of ceasing.

This memoir would be quite incomplete if it did not point out that (in addition to his specific engineering undertakings) he was also a public-spirited citizen. He frequently contributed to social discussions in the press and he addressed socialistic gatherings always with the idea expressed by him: "The hope of future generations lies in the evolution of a race which has judgment, foresight, and providence; and we cannot hope to produce it by giving people the "sheltered life." He believed in democracy with a minimum of government and he refers to Socialism as representing a maximum of government. "As our society becomes more complicated the activities of government must extend, but for growth and productiveness we must always look to the individual and if his opportunities are much restricted, our civilization must correspondingly shrink." To him, civilization was a going process and not merely a product.

It has something changeable for better at all time,—not static, but hugely dynamic, with possibilities which are limited only by the degree of personal liability and personality which our form of government has fostered in its people.

He was a democratic worker too and highly appreciated the contributions to industry which come from men who take pride in their individual skills. This was the advantage of large organization which Emmet understood. Why Europe is not more productive of inventions than America, he ascribed to "too much dependence on learned doctors rather than on the common man of little education." "Europeans tend towards being somebody while Americans tend toward doing something." The initiative of individuals can create an interlocking system where any pretext of rank in the group is displaced by rising individual ability. In absence of such contribution, "society tends to become less ebullient and the rise of native ability becomes less easy and natural." He often expressed great interest in the fact that everywhere in nature, not only among men, there exists the great mass of general activity in which a few individuals by unusual mobility, rise to visible heights of some sort of helpful service. They are abnormal but they determine the rate of growth of civilization.

In support of my contention that Emmet was interested in things outside of his engineering work, and persistently undertook to contribute to many fields, I ought to mention such items as his publication on "The Formation of the Moon and Earth." This is not done to emphasize the fact that astronomers are still uncertain as to the relative contributions of volcanoes and falling meteors to the Earth or the Moon. They recognize falling bodies as contributing to the pock-marked moon-face, as Emmet suggested. But it was typical of him to select this subject for a Fortnightly Club address, where discussible papers were most desired. It was typical also that he had noticed that many of the Moon's "craters" looked more like spattered mud-holes than like extinct volcanoes. Most of us see in such cases about what the experts say they see. But Emmet usually looked for more. He knew about the Great Meteor Lake in Arizona and reasoned that meteors were not always few or isolated

cases. Why should not at the proper time, such falling bodies somewhat disfigure the face of the moon? Such ideas, acquired from thinking independently, and about "first causes," gave him interesting views of geology and cosmic actions, so, at his own expense, he published the above mentioned paper, which was later printed in The Scientific Monthly. The effects of such efforts, when based on observation, make people think and that was his aim. A written reference to this is also interesting: "To this moon and earth theory, which is only in part original with me, I have given a good deal of study and I think my ideas are valuable."

Here is another example of the way he actually worked. Any new undertaking usually involves some risk. It has the peculiarity that not all its dependent parts can be found at the beginning. Some essential portions must be sought and discovered. This calls for faith. Judgment and reason testify that much yet unknown always responds to new effort. It is a bold engineer who does not put safety first, but how may one know just how far to depend upon future discovery to insure his new ideas? In case of the mercury boiler, Emmet had left as little to chance as possible, but it was not realized that there would be an actual dissolving action of mercury on steel. Everyone knew that mercury was kept indefinitely in iron containers. Nevertheless at the temperature of preferred design, he discovered a low rate of solution of the iron. This meant possible ultimate loss of valuable mercury from holes eaten through the hottest part of the boiler. Emmet's planning now showed his skill. He called for a detecting device which would show the slightest trace of escaping mecury in the stack-gases. The device had to be more sensitive than any existing means. Several types were then invented and so arranged that the slightest leak would start the operation of warning and shut-down apparatus. Meanwhile a different group of experts was asked to devise means of preventing this dissolving action. For this he chose "Tony" Nerad, a research man after his own heart. With various hypotheses they made countless experiments. Any hypothesis, if tangible, was forcefully applied. Many such had to be abandoned. Finally a certain mixture of very small quantities of rare metals

proved the boiler life-saver. No one could have safely predicted this result, and few could explain it when it was proved. My point is that the attempts were a part of Emmet's risking and persisting technique.

After he had experienced the uncertainties of early years, and had begun devoting his unusual energies to the electrical field, he still spent himself generously upon many of the details of the rapidly expanding work. But consistently he seemed to be planning for some distant future. Everything which could simplify electrical applications was of interest to him. Every new suggestion for increased economy appealed to him. In mid-life he had applied himself to the pressing needs of current problems, gradually he extended himself into the future possibilities. He never stopped trying to find methods which might give more electrical energy "per pound of coal." His path is clear as he went from lighting and railway applications through steam and water-power generation to the entirely new applications. His foresight also included the development of his assistants and of other young engineers generally, as though he saw those unlimited fields of mechanical futures which our growing sciences make certain. His electric drive for ships was one step, but his mind saw others more promising and more difficult. When he was only part way through work on mercury boilers and turbines for the largest power-stations, he had tempting visions of mercury boilers on locomotives and in ships. The possible physical and electrical dimensions seemed to promise well in such fields. It was thus, to him, but a natural step to mercury-power in aeroplanes. He was guided by the outstanding fact that (other things equal) the greater the differences between the temperature of boiling and that of practical condensing, the greater the efficiency of a boiler. Mercury was "compact," need never be lost, could be boiled at any temperature that metals could stand, etc. Perhaps his incompleted visions will appeal to others later, but it was natural that he should have had them. He had many other visions in old age without having been called "visionary." He based his views on facts he knew something about, and he hoped obstructions either of men or materials could be removed by sufficient effort.

Thus his latest efforts were mostly directed toward lowering the cost of "prime electric power." It was a problem worthy of his metal. To the company for which he worked, it was no secret that new uses beyond the original ones of Edison (incandescent lighting) began to make the cost of lighting quite negligible. Every farm-house and barn, every city-home could be economically lighted. But how and where might the applications of power which was so conveniently carried by wires do a better job? This has been a constant problem. It attracted the individualist, Emmet, and was his final worth-while life-work. The larger the power plant (generally) the cheaper the power per unit. The more differing useful devices "on the line," the more the cost per item could be reduced. For many items, the service became practically costless but priceless, after the wires were in. The radio, home-movie, furnace-control, door-bells, clocks, etc., need current, but consume so little as to be negligible. Thus with the steadily increasing applicability of the current, there was a natural desire on Emmet's part to appreciate it all. By that I mean to add to it; and so he continued to see new uses until his death at eighty-two.

From men who came closest in contact with Mr. Emmet in his life-work, I quote first from Mr. E. W. Rice. Thus he who had, through many strenuous years, supported the new and untiring efforts of his leading engineer (a most unpeaceful job) could later write: "I became acquainted with Mr. Emmet about 1894 and was immediately impressed with his character and peculiar ability. Those who know him best have found, behind the determined demeanor, the fierce love of truth, the hatred of cant, a wholesome lovable personality, a strong man who carries within his big body a great loving heart and who has fairly won that most precious thing in life—the love of his fellow-men."

From perhaps his closest engineering assistant, Bevis P. Coulson, Jr., the following: "Salient characteristics: untiring energy, great persistency and courage. Always in search of a reason for everything. Capable of seeing a clear mental picture of the whole problem and at the same time without neglect of the smallest detail. Capable of foreseeing the future possibilities of an engineering project. Best judge of character and ability of

men I have ever known. Never tired of thinking and repeatedly saying: 'It is thinking that counts.' Persisted in promoting only engineering projects that he knew to be worthwhile. Capable of aptly expressing his views. Always glad to discuss his problem with anyone who was interested. Did not suffer fools gladly. Persisted in experimentation."

Emmet was at one time vice president of the American Institute of Electrical Engineers, also a member of the American Society of Mechanical Engineers, of the Society of Naval Architects and Marine Engineers and of the National Academy of Sciences. Both Trinity and Union Colleges gave him the honorary degree of Doctor of Science. He also received the Gold Medal of the St. Louis Exposition and the Gold Medal of the San Francisco Exposition.

In 1909 he received the Edison Medal and in 1920 the Elliot-Cresson medal of the Franklin Institute. He also received the Gold Medal of the American Society of Mechanical Engineers and in 1938 The American Society of Architects and Marine Engineers awarded him The David W. Taylor Medal.

He died at his nephew's home in Erie, Pennsylvania, September 26, 1941, and was buried with Naval Honors in the National Cemetery at Arlington.

# A COMPREHENSIVE—BUT NOT COMPLETE—BIBLIOGRAPHY OF THE WRITINGS OF W. L. R. EMMET

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

*Transactions*

Discussion: Marine steam turbine development and design. Vol. 13, pp. 278-80, 1905.

Application of electricity to propulsion of naval vessels. Vol. 17, pp. 197-222, 1909.

Discussion: The best arrangement for combined reciprocating and turbine engines on steamships. Vol. 19, pp. 206-07, 1911.

Automatic record of propeller action in an electrically propelled vessel. Vol. 19, pp. 255-57, 1911.

Discussion: Engineering progress in the U. S. Navy. Vol. 20, pp. 75-77, 1912.

Discussion: An electrically propelled fireproof passenger steamer. Vol. 20, pp. 187-90, 1912.

Electric propulsion of U. S. S. *Jupiter*. Vol. 21, pp. 191-200, 1913.

Discussion: The applicability of electric propulsion to battleships together with the experience gained with it on the *Jupiter*. Vol. 22, pp. 198-201, 1914.

Some comparisons relating to electric propulsion of a battleship. Vol. 23, pp. 71-88, 1915.

Discussion: Theory of fluid friction. Vol. 24, p. 82, 1916.

Discussion: On the suitability of the current design of submarines to the needs of the U. S. Navy. Vol. 24, pp. 120-21, 1916.

Alquist gearing for ship propulsion. Vol. 24, pp. 181-94, 1916.

Discussion: Progress in turbine ship propulsion. Vol. 26, pp. 79-80, 1918.

Discussion: The propulsive efficiency of single-screw cargo ships. Vol. 27, pp. 133-34, 1919.

Electric propulsion of merchant ships. Vol. 27, pp. 277-99, 1919.

Discussion: Electric propulsion of ships. Vol. 29, pp. 123-25, 1921.

Discussion: The central power station goes to the sea. Vol. 36, pp. 259-60, 1928.

MARINE ENGINEERING

Ship propulsion by the mercury vapor process. Vol. 43, pp. 31-32, Jan., 1938.

A mercury propelled cargo ship. Vol. 46, p. 80, Feb., 1941.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS—PUBLICATIONS

*Journal*

Electric propulsion of ships. Vol. 34, p. 373, 1912.

*Mechanical Engineering*

Emmet mercury vapor process. Vol. 46, p. 235, 1924.
Carnot's influence upon engineering. Vol. 57, p. 426, 1935.
Status of Emmet mercury-vapor process. Vol. 59, p. 840, 1937.
Emmet mercury process. Vol. 59, pp. 957-58, 1937.
Mercury cargo ship. Vol. 62, pp. 911-12, 1940.
Mercury vapor for central station power. Vol. 63, pp. 351-56, 1941.

*Transactions*

Steam turbine in modern engineering. Vol. 25, p. 1041, 1904.
Emmet mercury-vapor process. Vol. 46, p. 253, 1924.

JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS

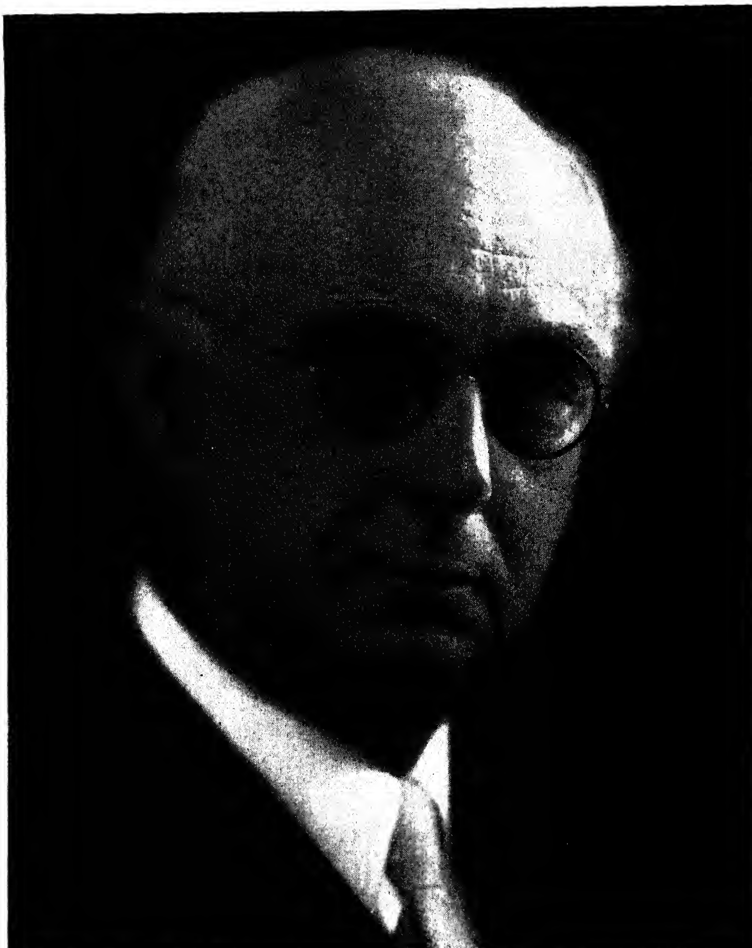
Some comparisons relating to electric propulsion of a battleship (*California*). Abst. Vol. 28, p. 231, 1916.
Electric drive for merchant ships. Vol. 31, p. 541, 1919.
Development of engineering talent in the navy. Vol. 33, p. 64, 1921.

MISCELLANEOUS PERIODICALS

Why electric drive is being recognized. Naut. Gaz., Vol. 114, p. 615, 1928.
Economies of the Emmet mercury vapor process for steam and power generation. National Engr., Vol. 32, p. 261, 1928.
Diesel vs. turbo-electric drive. Shpbldg. & Shpg. Rec., Vol. 31, p. 640, 1928.
10,000 kw. mercury unit cuts fuel bills $8000 a day. Elec. World, Vol. 94, pp 969-77, Nov. 16, 1929.
Emmet mercury vapor process—results accomplished. G. E. Review, Vol. 32, p. 619, 1929.
Results of mercury vapor cycle at Hartford. Power Plant Engr., Vol. 34, p. 378, Ap. 1, 1930.
A mercury-propelled cargo ship. Shipbldr. and Marine Engine Bldr., Vol. 48, pp. 176-78, April, 1941.

BOOKS

Alternating current wiring and distribution. New York, 1898. 96 pp.
Autobiography of an engineer. 1st ed., Albany, N. Y. Fort Orange Press, 213 pp., 1931. 2nd ed., New York, American Society of Mechanical Engineers, 1940, 226 pp.



George Ellett Coghill

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—TWELFTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# GEORGE ELLETT COGHILL

1872–1941

BY

C. JUDSON HERRICK

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1942

# GEORGE ELLETT COGHILL

## 1872–1941

BY C. JUDSON HERRICK

George Ellett Coghill was a philosopher before he was a biologist. At Brown University he followed the conventional classical course, graduating in 1896 with the A. B. degree. At twenty-five years of age, without professional training in philosophy, psychology or biology, during several months of solitary meditation he pondered the issues of a naturalistic philosophy which was consonant with his own way of thinking. The problems with which he struggled were essentially psychological; accordingly, he resolved to try to penetrate to the root of the matter and devote himself to an inquiry into the natural history of the human mind.

He realized at the outset that the biological approach offered promise, for the key factors probably lie in the nervous system. It was also evident that one lifetime is too short for that professional training in philosophy, psychology and biology requisite to round out the program. The obvious answer was to begin at the beginning and qualify himself as a biologist. This he did. Though most of his published research is strictly biological, the philosophical interest never waned and he was alert for the psychological meaning of his findings. His reading covered a wide field and was directed toward psychological interpretation and philosophical integration, as testified by voluminous notes, extracts and comments, all systematically filed and indexed. This background perhaps explains the curious fact that, though he was expert in neither philosophy nor psychology, his work received wider recognition in the psychological field than among his biological colleagues.

He was born at Beaucoup, Illinois, on March 17, 1872, the fifth of a family of seven children of John Waller and Elizabeth Tucker Coghill. He was reared on a farm near Roseville, Illinois. On September 13, 1900, he married Miss Muriel Anderson and to them five children were born, Robert DeWolf, James Tucker, Louis Waller, Muriel, and Benjamin Anderson. He is survived by these children and their mother.

He attended Shurtleff College for two years, then transferred to Brown University. His biological training began at the University of New Mexico, which he entered as a graduate student in 1897 and left with the rank of assistant professor of biology in 1900; it was continued at Brown University, 1900 to 1902, when he received the Ph. D. degree in biology. During several collegiate appointments from 1902 to 1913 and as professor of anatomy in the University of Kansas from 1913 to 1926 a secure factual foundation was laid by unremitting observation and experiment and this accumulation of data continued until his death at Gainesville, Florida, on July 23, 1941. During the decade, 1926 to 1936, he held a research appointment as member and professor of comparative anatomy at the Wistar Institute of Anatomy and Biology, Philadelphia, and during this period the chief conclusions reached were formulated in lectures and brief published papers. He was elected to membership in the National Academy of Sciences in 1935.

The years 1936 to 1941 were spent in retirement. Though broken in health and at times completely incapacitated, these years were productive. He continued his research as strength permitted, aided by grants from the Josiah Macy, Jr. Foundation, and had in preparation a comprehensive work to be entitled, "Principles of Development in Psycho-organismal Behavior" designed to present a psychological and philosophical synthesis of his studies on organismic development and the significance of mentation in these vital processes. Unfortunately this manuscript was left unfinished.

The nervous system was envisaged as a going concern the business of which is to maintain efficient coordination of the internal activities of the body and to ensure appropriate adjustment of the animal with its environment. Anatomical structure is meaningless apart from what it does. In all of his work this attitude is manifest. Every detail of structure and every observed activity was consistently examined in its relations with the organism as a whole. The program was so purposefully planned that every line of inquiry begun was directed toward a definite end and was set in its appropriate place without fumbling or lost motion.

The most significant outcome of this series of researches is the impressive demonstration of the unity and integrity of the organism and the dominance throughout life of the "total pattern" over "partial patterns" of behavior. Most behavior results from local and transient disturbance of this equilibrated system. There are many subordinate centers of dominance with more or less local autonomy, but these develop and continue to operate within the frame of the organismic whole and any permanent distortion of balanced interaction within this hierarchy of integrated units is abnormal. The nervous system is the chief, though by no means the only, agency employed in the maintenance of normally balanced vital functions, and the research program was directed primarily to the discovery of the actual apparatus involved.

These generalizations may be formulated as one views the program in retrospect. They matured slowly in Dr. Coghill's mind, not as logical deductions from philosophic premises, but from the evidence accumulated as the research progressed. There is no evidence of any philosophic "system" at the start. On the contrary, problems were attacked with an open mind singularly free from preconceptions and distrustful of dogma, conventional methods and traditional formulations. This is illustrated by a remark in his early account of the behavior of Triturus larvae in 1909, where he writes, "tabulated schemes for rapid recording were tried in my first experiments of 1906, but it soon became apparent that such forms could not be adhered to, for they were necessarily based upon presumptions of some sort and were, therefore, a hindrance rather than a help to alert observation."

The original purpose was to find out what animals do with their nervous systems. Direct observation of the nervous tissues in action was impossible. At that time no technique was available for this, but overt behavior was observable. The problem was to find some way to correlate this behavior with the nervous tissues which activate and regulate it. Some progress had already been achieved by indirect methods of experiments on animals and by neuropathological studies, but a more direct approach was sought.

About forty years ago he resolved to attack this problem genetically. The late Stewart Paton was at that time (unknown to Coghill) investigating reactions of vertebrate embryos and associated changes in the nervous system; but his objective and methods were radically different from Coghill's, for he dismissed the study of specific reactions as impractical and aimed to discover how far the behavior in general is dependent upon "the functional activity of a nervous system." This specific relation is exactly what Coghill proposed to investigate.

Doctor Coghill's plan was to select some primitive and generalized species of animal with simple behavior and a nervous system which is correspondingly simplified, though not beyond the limit where comparison with human structure is practicable. The first step would be to follow the development of this animal from egg to adult, recording the sequence of changes in patterns of overt behavior from the first muscular movements. These observations made on statistically adequate numbers of specimens at each stage in the elaboration of the behavior pattern would establish for the species studied a norm or standard of developmental stages from the simplest to the completed action system of the adult. The records would include both spontaneous behavior and responses to various standardized methods of stimulation. The next step would be the preservation of large numbers of specimens each of which was known by test to have reached a particular and definable stage of physiological development. Microscopic study of these specimens would, it was hoped, reveal a series of changes in bodily structure correlated with the physiological stages previously established. Finally when the physiological and the anatomical data are assembled and fitted together the bodily organs concerned with successive phases of the functional development are revealed. With each increment of the developing complexity of the behavior pattern some specific activity is seen in sharp relief for which a corresponding change in bodily structure would be sought.

This program obviously would be exceedingly laborious and exacting and it should be carried on cooperatively by a team of qualified investigators; nevertheless Coghill resolved to attempt

it single-handed. To this resolve he steadfastly adhered for the remainder of his life, with industry, insight and productiveness rarely equalled. The results have justified the labor and sacrifices—and these were very large. The obstacles encountered would have been insuperable to a man of less intensity of purpose and indomitable persistence. During the years 1902 to 1913 he held appointments in small colleges with a heavy teaching schedule and no assistance of any kind. The tedious physiological experiments and the preparation of enormous numbers of serial sections had to be done with his own hands after long days of fatiguing duty.

As objects of study he selected the salamanders, whose eggs are abundant, easily reared and observed, and tolerant of a wide variety of experimental procedures. Among these Amblystoma was an especially fortunate choice, for during the span of forty years of his labor this has proved to be the most serviceable type for a wide range of experimental researches at the hands of numberless other investigators. The common frog has been the handmaid of physiology for centuries, beginning even before that memorable day when Galvani hung some frogs' legs on an iron railing with brass hooks and saw them twitch from the electrolytic currents generated; and Coghill's first observations were upon anuran tadpoles. He promptly transferred his attention to the salamanders, which since that time have displaced the frogs from their preeminence in the field of experimental embryology. Here he broke new ground in both objective and methods of work.

With Dr. Coghill the total behavior of the animal was under observation and knowledge of the anatomical structure of the body as a whole was essential for its interpretation. In this connection the subject chosen for his doctor's dissertation is significant—"The Cranial Nerves of Amblystoma tigrinum." In this, his first major scientific contribution, he gained the necessary familiarity with the structure of the animal whose development he later studied.[1] This paper is not descriptive anatomy of the traditional sort, but each peripheral nerve is analyzed microscopically into its components as functionally defined and in his subsequent studies the development of each

of these components is separately described. This dissertation laid a secure foundation for all subsequent work. His program included, in addition to study of the differentiation of the nervous system in correlation with the sequence of development of behavior patterns, also parallel descriptions of the development of blood vessels, organs of digestion, excretion, etc. Some of the latter studies were begun in collaboration with his students, but not carried to completion. In view of the great amount of research which has been done on Amblystoma, these studies should be continued, and this would seem to be the next step toward the realization of Dr. Coghill's ideal.

Doctor Coghill's first teaching positions were in Oregon, where Amblystoma was not readily available. It would have been possible to secure the eggs from the east, for they survive shipment very well. This was not tried, and fortunately so, for later experience taught him that, though Amblystoma eggs grow apparently normally after long shipment, their subsequent behavior is atypical. The first physiological observations were made upon Triturus (Triton, Diemyctylus) torosus and these were later repeated with Amblystoma. The findings were similar, and this is explained by the fact, recently demonstrated by Dr. G. P. DuShane, that the pattern of development of Triturus closely resembles that of Amblystoma. The cranial nerves of Triturus were described by Dr. Coghill at this time (1906) from specimens of T. tæniatus which were given to him by Dr. Th. Boveri, with whom he studied in Würzburg in 1902.

It was not then known whether the earliest movements of these embryos were haphazard and disorderly or performed according to some observable system. This question was soon answered and an orderly sequence of reactions to stimulation and of spontaneous movements was described in the paper of 1909.

The preliminary experiments showed that the most useful criteria for staging the developing embryos physiologically were their reactions to tactile stimulation. A fine human hair was brushed lightly over the skin and reactions recorded. He early noted that "the extreme sensitiveness of some very young

embryos is remarkable" and took special precautions to distinguish between "reflex," i. e., neuromuscular responses, and myogenic movements called forth by direct pressure upon the reacting muscles. The neglect of these precautions by some subsequent students of embryonic behavior has resulted in much confusion. In these amphibian embryos the distinction between neurogenic and myogenic responses is sharp and clear at the hands of a careful and experienced observer.

In the course of further experimentation the spontaneous movements of these embryos were carefully observed and their sensitivity to electrical, chemical, visual and other stimuli was explored. In the staging of the younger specimens responses to light tactile stimulation of the skin continued to be the chief reliance. At more advanced ages a large variety of other criteria were employed as the patterns of behavior changed.

In the paper of 1909 the sequence of changes in response to light tactile stimulation was recorded, but the growing embryos were not grouped in named or numbered physiological stages. In later reports, after the observations had been repeated with Amblystoma and amplified, the following physiological stages were defined: (1) premotile, including all early stages which exhibit no movement of somatic muscles; (2) nonmotile, with only myogenic movements executed spontaneously or resulting from direct stimulation of the muscles; (3) early flexure, characterized by the first neuromuscular responses; (4) coil, when the embryos execute spontaneously or in response to stimulation spasmodic unilateral contractions resulting in a tight coil; (5) S-reaction; (6) early swimming. These stages are demonstrable in the embryos and are clearly defined. The staging of larvae after hatching from the eggs presents more serious difficulties and these problems are even now still under investigation.

During this period Dr. R. G. Harrison had been engaged upon a morphological staging. A series of specimens of Amblystoma from the unsegmented egg to the first feeding reactions was separated into 46 stages, representatives of which were carefully drawn. Though these pictures have not been published, photographs of them have been supplied to other workers in

this field and frequent references to Harrison's stages are in the literature. In 1933 Dr. W. T. Dempster published observations on the growth of Amblystoma in early stages, and from 1937 to 1941 the present writer issued a series of papers describing the internal differentiation of the brain from the coil stage to the adult, with a provisional correlation of Coghill's and Harrison's stages. Currently Doctors DuShane and Hutchinson are engaged upon a more critical study of the growth of Amblystoma under rigidly controlled conditions which it is hoped will clarify a confused situation.

From all of these studies it is clear that the growth and differentiation of Amblystoma under natural environmental conditions cannot be reduced to any single series of formulae. Coghill's physiological series does not run exactly parallel with Harrison's morphological series, and in the differentiation of internal structures the various organs do not keep step with one another or with the development of external form. In view of these rather wide deviations from any single standard or norm of development and the number of unknown variables, the only practicable procedure has been to select some particular criterion of structure or function and stage the specimens under investigation with reference to it. Thus Coghill writes, "after locomotion by swimming is established, the development of behavior in Amblystoma may be regarded as following two courses towards different goals: the one leading to the capture of prey and swallowing it; the other to terrestrial locomotion by walking." These two courses do not necessarily run parallel, but may vary independently, and Coghill's later studies were devoted to the development of the limbs as organs of locomotion and specifically to the relation of these "partial patterns" of movement to the "total pattern."

The stages from swimming to feeding were grouped as early swimmers, strong swimmers, late swimmers and, preceding the first feeding reactions, short periods of active avoiding and nonresponsiveness. Movements of the limbs begin shortly before the time of the first feeding reactions, and the sequence of this development was outlined to me in a letter of May 26, 1926:

"Following swimming, events come in the following order:

gill movement coordinated with trunk movement, discrete gill movement (along with fore limb movement), fore limb movement coordinated with trunk movement, discrete arm movement, elbow flexion coordinated with arm movement, discrete forearm movement, hand movement integrated with arm movement, hind leg movement integrated with trunk movement, knee flexion integrated with leg movement, discrete knee flexion, toe movement integrated with leg movement."

From this he concludes (in a statement published ten years later—J. Genetic Psychol., vol. 48, p. 6):

"Terrestrial locomotion, like the aquatic, is also a total action pattern in Amblystoma. . . . In the beginning of the walking gait, therefore, the limbs function wholly as integral parts of a total pattern of action without any intervention of local reflexes. Local reflexes of the limbs appear later, as the limbs become a factor in orientation of the animal with reference to a surface."

Doctor Coghill's conception of the "total pattern" has been frequently misunderstood, even by his own disciples and sympathetic critics, with resulting confusion. If authors use the same word with different meanings, controversy is almost inevitable regarding both factual description and interpretation. In his earlier papers this expression was used in a restricted sense which was not clearly defined. His later references indicate a broader connotation, but unfortunately the relations between the larger total pattern and the subordinate patterns are not explained in sufficient detail and misunderstanding has resulted. The apparent ambiguity disappears when the earlier condensed statements are read in the light of the subsequent discussions of the apparatus of integration.

As already pointed out, the mature organism is regarded as an hierarchy of local units, each with some measure of autonomy and all bound together as an integrated whole. During the maturation of the neuromotor apparatus these local units are so interconnected that the first overt movements to appear are orderly sequences of behavior, not haphazard nor convulsive action. In subsequent stages, with increase in the complexity of the local apparatus, these "partial patterns" remain throughout life under the control of the "total pattern" of the organ-

ismic whole. The apparatus of integration takes various forms —nervous and non-nervous—but in the normal animal the dominance of the total pattern is never lost. Thus Coghill wrote in 1940, "'Pattern' connotes organization, and 'total pattern' expresses the organization of the whole individual for purposes of behavior."

In a study of the embryogenesis of animal behavior these two factors must always be kept in view, for they are indissociable—the presence of local and more or less autonomous organs and the dominance of the organism-as-a-whole over all of them. These factors are sometimes antagonistic, but they are not mutually exclusive. Without this dominance orderly development would be impossible and without some measure of local autonomy differentiation cannot go on. The problems of organogenesis and total integration go hand in hand.

In the development of Amblystoma this relationship appears with unusual clarity. According to widely current theory the complicated action system of the adult is built up by combining simple reflex units into progressively more and more complex systems. But when Dr. Coghill watched the development of salamanders and followed the successive steps in the elaboration of the action system of the skeletal musculature, he found no simple local reflexes. On the other hand, the first neuromuscular responses to appear were contractions of large masses of the muscle of the trunk, the mass increasing as the nervous and muscular organs matured, until in response to a single stimulus practically all of the trunk musculature was involved in an efficient swimming movement. This is a total pattern of behavior resulting in aquatic locomotion.

At this "early swimming stage" there are no limbs and all visible somatic movements are at first of total pattern type. As limbs develop and their movements are individuated, these movements emerge within the total pattern and as parts of it. Movements of the limb as a whole and of the separate parts of it are progressively emancipated from immediate participation in total movement and the aquatic type of locomotion is transformed into the terrestrial type, with separate action of the limbs and their members. In Amblystoma this emancipa-

tion of the partial patterns of the limbs is never complete and adult walking normally involves some total bodily movement of the swimming type. Even in birds and mammals, where limb movements may be executed quite independently of any visible overt movement of the trunk musculature, it remains true that the local activities of the limbs are to some extent subordinate to and under the control of the total pattern of the organization, for flying and walking are usually directed somewhither and this direction does not reside in the members which execute the movements.

The preceding description applies to Amblystoma and only to the development of somatic movements of the trunk and limbs. For these it seems to be well validated; but it does not follow that the same sequence of events will appear in the development of other systems in Amblystoma, say of eye movements or visceral movements, or of limb movements in all other animals. The last point was investigated incompletely by Dr. Coghill in some fishes, reptiles and mammals. These studies were unfinished and the details are unpublished, but they convinced him that fin movements in killifish and toadfish and limb movements in reptiles and opossums in early stages of development are integrated with trunk movements much as in Amblystoma.

In these facts Dr. Coghill found no support for the current doctrine that complex behavior patterns are synthesized by accretion of discrete reflexes. Quite the contrary, the integration is primary and the analytic functions are secondarily developed within the total pattern. These partial patterns, in turn, may subsequently be synthesized into an indeterminate type of behavior of infinite variety, again under the influence of higher "supra-sensory and supra-associational centers" of integration (Proc. Nat. Acad. Sci., vol. 16, 1930, p. 642).

The evidence for this conclusion was presented, for Amblystoma, in detail up to maturation of the swimming movement, together with an account of the correlated development of the anatomical structures involved. The history of the individuation of limb movements is quite different and study of the structural changes involved was in process at the time of his death. Had he been permitted to carry these studies to conclusion, it

is probable that his formulation of the relations between partial patterns and total patterns would have been amplified in form different from the concise and over-simplified statements in the earlier papers.

At the beginning he was confronted with the necessity of clearing the ground of some misconceptions in current doctrines of reflexology. He found in early stages no discrete local reflexes and no isolated reflex arcs. The present writer, who has devoted considerable attention to the histological structure of the brains of these salamanders, reports that even in the adult animal there is no such thing as a discrete reflex arc anywhere. The apparatus of the action system is not built of such units, but the structural specifications are according to a different plan in which the apparatus of integration is paramount and local individuation is at a minimum as compared with more highly differentiated brains.

Doctor Coghill, accordingly, emphasized the point at issue—the primacy of the integrative functions and total patterns—which comes out more clearly perhaps in his material than in any other vertebrate species which might have been chosen. In generalizing this conclusion in the broad biological terms laid down here he is on safe ground; but it is not safe in any particular instance to anticipate that the process of individuation of any organ will follow the same lines in detail. He was not unmindful of this point and it is unfortunate that he did not give it more explicit emphasis in his published writings.

During the developmental process, up to and including the adult, the partial patterns are initiated, differentiated and operated within the total organismic pattern and influenced by it. This influence may be manifest in overt behavior, as in the entire history of limb development of Amblystoma, or the process of emancipation may be accelerated in the central nervous adjustor so that the first overt movement of the limb is a local reflex.[2] In both cases the limb mechanism is never entirely free from some measure of subordination to the total organismic pattern.

Now to recur to the question of definitions. If one defines the concept of total pattern broadly in organismic terms, as Coghill evidently did, it is probable that few competent biologists or

psychologists would controvert the thesis that the whole is greater than the parts and that in the living body the parts are under some measure of control by the organism-as-a-whole, i.e., that all partial patterns are subordinate to the total pattern. This total pattern is a complex hierarchy of local centers of dominance over subordinate parts with varying grades of autonomous activity. In any experimental program some particular component of this complex is selected for intensive study out of its total context, such as, for instance, aquatic or terrestrial locomotion. "Total" and "partial" are here relative terms to be interpreted in the light of the context in which they are used. In the context before us they are restricted to visible overt movement of skeletal musculature.

This is explicitly so stated in the manuscript of an unpublished lecture delivered at the University of Minnesota in April of 1930, where he wrote, "There is nothing immaterial in mind when I use the term pattern. I try to use it consistently to designate configuration or form of action or inhibition. When all overtly mobile parts of the animal appear to be in action I call the performance a total action pattern. When only a part of the overtly mobile animal is in action I call the performance a partial action pattern." In the monograph of 1940 Dr. Coghill says, "the whole individual probably acts in every response, either in an excitatory or inhibitory way. Therefore, while overtly the individuated part acts apparently independently of the total pattern, the latter participates in its performance by inhibition."

In this restricted sense there are instances, like the limbs of Amblystoma, where the partial pattern is at first tightly bound to the total pattern and in later stages progressively emancipated from these bonds. These instances were critically studied and described in detail by Dr. Coghill because they supply easily demonstrable factual data in support of his main thesis that the living body is not an assemblage of particulars built up by accretion, but an integrated unity from beginning to end. The patterns here demonstrable are not unique, but are found to recur with more or less variation in many other situations. These patterns, accordingly were regarded as typical illustrations

of his larger conception. He would not have claimed that the development of all partial patterns must conform with the paradigm here laid out, though his own program had not advanced far in the exploration of other types of development.[3]

Most of the factual material published after his appointment in the department of anatomy at the University of Kansas is included in the twelve parts of his "Correlated anatomical and physiological studies of the growth of the nervous system of Amphibia" published from 1914 to 1936. These papers are models of close, accurately controlled observation and clear description, but they are not easily read, for the technical details are recondite and intricate. Skillful analysis marshals the evidence in intelligible and convincing form. The present writer has verified many of the observations upon the younger stages, using the original preparations, and he has confirmed and extended the descriptions of more advanced stages upon other material prepared by different methods. Other collaborators make similar reports. The accuracy of Coghill's descriptions is amply validated.

These papers cannot be summarized here, nor is this necessary, for their author has reviewed their salient features and has interpreted them more clearly and graphically than any commentator could hope to do. These studies, he says, "were undertaken with a view to correlating specific structure, in particular animals, with known physiological characteristics of those animals," and the measure of his success in this difficult enterprise exceeds that of any of his predecessors or successors.

The topics treated include an analysis of the afferent systems, central and peripheral, at successive stages of physiological development, a similar analysis of the efferent systems, and detailed accounts of the development of the apparatus of correlation and integration. Paper 10 of the series (1931) discusses some corollaries of the study of early development to the swimming stage. Papers 11 (1933) and 12 (1936) begin a new series of studies on the differentiation of the limbs and the relation of their local functions to the total pattern of behavior. It is hoped that these unfinished studies may be continued by some of his younger colleagues who collaborated in this program.

The ten papers of the first series deal with the development of the embryo up to the stage when locomotion by swimming is acquired. "During this period," he says, "the behavior pattern is an integrated unit, and the structural development of the nervous system is such as to maintain this integrity through the growth of functional neurons." Another important finding is the demonstration of the precocious differentiation of the motor systems and the early maturation of these and also of the sensory and correlating apparatus by intrinsic agencies in advance of any peripheral influence.

Clear and concise summaries of the observations recorded in the twelve "studies" are available in several of the published lectures, together with interpretations and applications to specific biological and psychological problems. The titles of these brief papers as listed in the accompanying bibliography reveal the scope of his interests and their content expresses profound and incisive thinking. Special mention should be made of two of these publications: (1) the lectures delivered in London on "Anatomy and the Problem of Behaviour" (Cambridge University Press, 1929), and (2) the presidential address before the American Association of Anatomists on "The Neuro-embryologic Study of Behavior: Principles, Perspective and Aim" (Science, vol. 78, 1933).

The psychological significance of the facts brought to light in this series of studies on embryogenesis had not been systematically formulated before Dr. Coghill's untimely death, though fragmentary suggestions are scattered through his later papers and lectures. Typical of these is the concluding passage of paper 10 of the "Studies."

"My object in this discussion is to show that . . . . . . . . . spontaneity of nervous action, in the sense that it has been presented above, is projected into the life of the individual through an indeterminate period, and that, therefore, sensorimotor response should not be regarded as constituting the whole function of the nervous system. Overt behavior actually occurs in some species as an expression of the intrinsic dynamics of the organism as a whole, and, in so far as the correlation of nervous structure and function in the development of the individual has been carried, structural provision has been found

for the perpetuation of spontaneity, autonomy, or initiative as a factor in its behavior. Any theory of motivation, therefore, that attributes this function wholly to the environment (Troland, '28) is grossly inadequate."

In this passage there is adumbrated a psychological principle to which he devoted much thought in his later years. Several years earlier (July 27, 1926), in reply to some comments upon the sixth paper of his "Studies," he wrote to me:

"In my opinion the most important thing in it is the demonstration of the wonderful capacity for growth that is retained by the nerve cell after it has become functional as a conductor. I am sure of the soundness of the observation histologically and see it amply corroborated in the development of movements in the limbs. . . . . . . I don't believe there is any break whatever between embryonic and adult performances, and that so long as adaptation to new conditions is possible functional nerve cells are growing somewhere in the nervous system in the same way that I see them growing in the ventral nerve roots."

This implies, as he later expressed it, that "learning is essentially growth, and mental hygiene is grounded in the growth of the nervous system." The spontaneous movements of the youngest motile embryos are internally activated and the pattern of their expression is determined by an intrinsic organization which is not dependent upon any sensori-motor excitation. "The organism," he says, "first acts on the environment and only later reacts to the environment." "The sensori-motor response, designated as the S R by psychologists, is a secondary form of behavior. Its primary function is orientation of the animal so that the action will be directed toward the appropriate end. But the sensory component of the system soon acquires the further role of activating and conditioning behavior." Thus we see that the later stages of intrinsic growth are modifiable by sensori-motor experience, but the internally generated spontaneity is not thereby reduced; on the other hand, it is amplified as the central adjustors increase in complexity of organization and integrative efficiency.

"The individual, certainly in the early stages, has much more nervous organization than can express itself in immediate behavior; and the higher the species in the animal scale, the larger

is this supra-sensory and supra-associational component of the nervous system" (Conference on Adolescence, Cleveland, 1930). These remarks remind one of Wm. James' writings on "The Energies of Men," and it is a pity that they were never amplified in print by Dr. Coghill.

If space permitted many similarly pregnant passages might be cited in justification of the words spoken by Dr. R. G. Harrison on the occasion of the award of the Elliot Medal of the National Academy of Sciences to Dr. Coghill on April 24, 1934:

"Dr. Coghill's pioneer work has won for him a place of high distinction. . . . . . . Progressive changes in reaction have been followed by Dr. Coghill step by step in individual embryos, and at each stage cases taken immediately after their reactions had been tested were preserved and studied microscopically. In this way the actual state of differentiation of the nervous system in each individual has been correlated with its behavior. . . . . . .

"Associated with differentiation, but in a certain sense antagonistic to it, is the process of growth, the study of which has required the counting of thousands of cells and charting their positions in the spinal cord and brain at various stages of development. This has involved an immense amount of painstaking work which would all have been to little purpose had the task not been approached by a man of broad knowledge and subtle insight. From all this has developed a new conception of the origin of nervous function. At no time does the nervous system work as a collection of independent reflexes, which later become integrated. On the contrary, at each stage it functions as a whole, expanding from stage to stage, and as development proceeds, various partial functions arise within it as more or less discrete reflexes. These investigations of Dr. Coghill will have a lasting influence in psychology and physiology as well as in embryology."

This summary may be further condensed into a few words taken from a letter written by Dr. Coghill on Feb. 8, 1930:

"For my own thinking the two important results of all my juggling with Amblystoma are the reality of a total-pattern mechanism, and a scientific basis for the conception of spontaneity, autonomy or initiative of the individual in behavior. In these two principles I get a different conception of motivation than I get from any other source."

## NOTES

In the preparation of this memoir free use has been made of appreciations published in *Science,* Aug. 29, 1941, *Journal of Comparative Neurology,* Oct. 15, 1941, and *Anatomical Record,* Feb. 25, 1942, and May 25, 1942.

The aim here is to present a concise summary of Dr. Coghill's scientific contributions, with some commentary. The more intimate details of a personal biography and intimations of the philosophic motivation of his work, with extracts from his published and manuscript papers, are reserved and may be published elsewhere.

[1] In the published thesis (Journal of Comparative Neurology, vol. 12, 1902) the ages of the specimens described are not recorded, but Dr. Coghill later informed me personally that the descriptions are based on serial sections of adults after metamorphosis and advanced larvae from 8 to 13 cm. long. The figures are from a larva 12 cm. long.

[2] Compare Donald H. Barron's statement: "The later in ontogeny a sensory nerve makes functional connexions with the central nervous system, the more restricted the motor response it elicits when stimulated may be expected to be."—The functional development of some mammalian neuromuscular mechanisms, Biological Reviews, vol. 16, 1941, pp. 1-31.

[3] See Dr. Coghill's discussion of Tracy's work in his presidential address, Science, 1933. Barron's comprehensive review (1941) already cited is of interest in this connection.

## BIBLIOGRAPHY

### KEY TO ABBREVIATIONS

Am. J. Psychol.—American Journal of Psychology
Anat. Rec.—Anatomical Record
Arch. Neurol. and Psychiat.—Archives of Neurology and Psychiatry
J. Comp. Neur.—Journal of Comparative Neurology
J. General Psychol.—Journal of General Psychology
J. Genetic Psychol.—Journal of Genetic Psychology
Ohio J. Sci.—Ohio Journal of Science
Proc. Am. Philos. Soc.—Proceedings, American Philosophical Society
Proc. Nat. Acad. Sci.—Proceedings, National Academy of Sciences
Proc. Soc. Exper. Biol. and Med.—Proceedings, Society for Experimental Biology and Medicine
Psychiat. en Neurol. Bladen—Psychiatrische en Neurologische Bladen
Psychol. Rev.—Psychological Review
Trans. Am. Neurol. Assoc.—Transactions, American Neurological Association

*1898*

The somatic equilibrium and the nerve endings in the skin. (With C. L. Herrick). J. Comp. Neur., vol. 8, pp. 32-56.

*1899*

Nerve termini in the skin of the common frog. J. Comp. Neur., vol. 9, pp. 53-63.

*1901*

The rami of the fifth nerve in Amphibia. J. Comp. Neur., vol. 11, pp. 48-60.

*1902*

The cranial nerves of Amblystoma tigrinum. J. Comp. Neur., vol. 12, pp. 205-289.

The branchial nerves of Amblystoma. (Abstract.) Science, vol. 15, p. 576.

Kingsley on the cranial nerves of Amphiuma. (A review with critical comments.) J. Comp. Neur., vol. 12, pp. xxiv-xxvi.

*1904*

Recent studies on the finer structure of the nerve cell. (Critical digest.) J. Comp. Neur, vol. 14, pp. 171-202.

*1906*

The cranial nerves of Triton taeniatus. J. Comp. Neur., vol. 16, pp. 247-264.

*1908*

The development of the swimming movement in amphibian embryos. (Abstract.) Anat. Rec., vol. 2, p. 148.

The reaction of amphibian embryos to tactile stimuli. (Abstract.) Science, vol. 27, pp. 911-912.

*1909*

The reaction to tactile stimuli and the development of the swimming movement in embryos of Diemyctylus torosus Eschscholtz. J. Comp. Neur., vol. 19, pp. 83-105.

*1913*

The primary ventral roots and somatic motor column of Amblystoma. J. Comp. Neur., vol. 23, pp. 121-143.

The correlation of structural development and function in the growth of the vertebrate nervous system. Science, vol. 37, pp. 722-723.

*1914–1936*

Correlated anatomical and physiological studies of the growth of the nervous system of Amphibia. Parts I to XII:

1914. I. The afferent system of the trunk of Amblystoma. J. Comp. Neur., vol. 24, pp. 161-233.

1916. II. The afferent system of the head of Amblystoma. J. Comp. Neur., vol. 26, pp. 247-340.

1924. III. The floor plate of Amblystoma. J. Comp. Neur., vol. 37, pp. 37-69.

1924. IV. Rates of proliferation and differentiation in the central nervous system of Amblystoma. J. Comp. Neur., vol. 37, pp. 71-120.
1926. V. The growth of the pattern of the motor mechanism of Amblystoma punctatum. J. Comp. Neur., vol. 40, pp. 47-94.
1926. VI. The mechanism of integration in Amblystoma punctatum. J. Comp. Neur., vol. 41, pp. 95-152.
1926. VII. The growth of the pattern of the association mechanism of the rhombencephalon and spinal cord of Amblystoma punctatum. J. Comp. Neur., vol. 42, pp. 1-16.
1928. VIII. The development of the pattern of differentiation in the cerebrum of Amblystoma punctatum. J. Comp. Neur., vol. 45, pp. 227-247.
1930. IX. The mechanism of association of Amblystoma punctatum. J. Comp. Neur., vol. 51, pp. 311-375.
1931 X. Corollaries of the anatomical and physiological study of Amblystoma from the age of earliest movement to swimming. J. Comp. Neur., vol. 53, pp. 147-168.
1933. XI. The proliferation of cells in the spinal cord as a factor in the individuation of reflexes of the hind leg of Amblystoma punctatum Cope. J. Comp Neur., vol. 57, pp. 327-358.
1936. XII. Quantitative relations of the spinal cord and ganglia correlated with the development of reflexes of the leg in Amblystoma punctatum Cope. J. Comp. Neur., vol. 64, pp. 135-167.

*1915*

The development of reflex mechanisms in Amblystoma. (With C. Judson Herrick.) J. Comp. Neur., vol 25, pp. 65-85. (Abstract in Anat. Rec., vol. 9, pp. 81-83).

Preliminary studies on intracellular digestion and assimilation in amphibian embryos. Science, vol. 42, pp. 347-350.

Salient features of the medulla oblongata of Amblystoma embryos of definite physiological stages in development. (Abstract.) Anat. Rec., vol. 9, pp. 68-69.

*1920*

The nervous nature of the floor plate in the neural tube of Amblystoma. (Abstract.) Anat. Rec., vol. 18, pp. 228-229.

*1921*

Proliferation and differentiation in the central nervous system of Amblystoma. (Abstract.) Anat. Rec., vol. 20, pp. 193-194.

*1923*

The growth of neuroblasts in relation to physiological gradients and differential rates of metabolism. (Abstract.) Anat. Rec., vol. 25, p. 124.

*1924*

Individual differences in proliferation of cells in the brain of Amblystoma. (With E. Stevenson.) Anat. Rec., vol. 27, pp. 165-174.

The development of the vascular system and pronephros as correlated with the nervous system and the behavior pattern in Amblystoma. (Abstract ) Anat. Rec., vol. 27, p. 200.
The vascular system in relation to neuromuscular functions in the early development of Amblystoma. (With Julia Moore.) Anat. Rec., vol. 28, pp. 131-148.

*1925*

The development of the pronephros in relation to the behavior pattern in Amblystoma. (With Fred L. Soper.) Anat. Rec., vol. 30, pp. 321-325.
Proliferation, differentiation, and orientation of cells as distinctive factors in the early development of the nervous system of Amblystoma. (Abstract.) Anat. Rec., vol. 31, p. 300.

*1926*

The capacity of function and of growth of the motor neurones of Amblystoma. (Abstract.) Anat. Rec., vol. 32, p. 204.
The growth of functional neurones and its relation to the development of behavior. Proc. Am. Philos. Soc., vol. 65, pp. 51-55.

*1928*

Localized centers of differentiation and polarity of nerve cells in the brain of Amblystoma punctatum. (Abstract.) Anat. Rec., vol. 38, p. 41.
The development of terrestrial locomotion in Amblystoma. (Abstract.) Anat. Rec., vol. 38, pp. 41-42.

*1929*

Anatomy and the problem of behaviour. Cambridge Univ. Press. 113 pp., 52 figs.
The development of movement of the hind leg of Amblystoma. Proc. Soc. Exper. Biol. and Med., vol 27, pp. 74-75.
The early development of behavior in Amblystoma and in man. Arch. Neurol. and Psychiat., vol. 21, pp. 989-1009.

*1930*

The structural basis of the integration of behavior. Proc. Nat. Acad. Sci., vol. 16, pp. 637-643.
The genetic interrelation of instinctive behavior and reflexes. Psychol. Rev., vol. 37, pp. 264-266.
Individuation versus integration in the development of behavior. J. General Psychol., vol. 3, pp. 431-435.
Delayed reproduction in Amblystoma punctatum. (With M. T. Caldwell.) Proc. Soc. Exper. Biol. and Med., vol. 28, pp. 21-22.
The development of half centers in relation to the question of antagonism in reflexes. J. General Psychol., vol. 4, pp. 335-337.
Anatomical growth of the nervous system in relation to behavior. Proc. Conference on Adolescence, Cleveland, Ohio, pp. 106-110. Published by

Brush Foundation and Western Reserve University under the title: Physical and mental adolescent growth.

*1933*

The neuro-embryologic study of behavior: principles, perspective and aim. Science, vol. 78, pp. 131-138.

The biologic basis of conflict in behavior. Psychoanalytic Rev., vol. 20, pp. 1-4. Published also in Trans. Am. Neurol. Assoc., 58th meeting, pp. 629-632.

Somatic myogenic action in embryos of Fundulus heteroclitus. Proc. Soc. Exper. Biol. and Med., vol. 31, pp. 62-64.

Growth of a localized functional center in a relatively equipotential nervous organ. Arch. Neurol. and Psychiat., vol. 30, pp. 1086-1091.

The growth of the nervous system and its relation to integration and motivation of behavior. Soviet. Psikhonevrol., vol. 9, no. 6, pp. 5-15. (Translation of Russian title. The text is in Russian.)

*1934*

The probable inhibitory function of Mauthner's fiber in Amblystoma punctatum. (Abstract.) Anat. Rec., vol. 58, suppl., pp. 55-56.

New anatomical relations and the probable function of Mauthner's fibers. Psychiat. en Neurol. Bladen, Jaargang, pp. 386-391.

*1935*

The development of the sensory system in relation to the local sign. (With A. W. Angulo y Gonzales.) Proc. Assoc. for Research in Nervous and Mental Disease, vol. 15, pp. 265-273.

*1936*

Integration and motivation of behavior as problems of growth. J. Genetic Psychol., vol. 48, pp. 3-19. (This is a revision of the original English text of the Russian paper of 1933.)

Effects of chilling on structure and behavior of embryos of Amblystoma punctatum Cope. Proc. Soc. Exper. Biol. and Med, vol. 35, pp. 71-74.

Review of Gesell's Atlas of infant behavior. J. Genetic Psychol., vol. 48, pp. 254-258.

*1937*

Embryonic motility and sensitivity. (With W. K. Legner.) Translation of W. Preyer's "Specielle Physiologie des Embryo," with Preface. Monographs of the Society for Research in Child Development, vol. 2, no. 6, serial no. 13, 115 pp. Pub. by National Research Council, Washington, D. C.

*1938*

Space-time as a pattern of psycho-organismal mentation. Am. J. Psychol., vol. 51, pp. 759-763.

An instance of progressive individuation in visual functions. Science, vol. 88, pp. 351-352.

Early movements of the opossum with special reference to the walking gait. Proc. Soc. Exper. Biol. and Med., vol. 39, pp. 31-35.

*1939*

Studies on rearing the opossum (Didelphys virginiana). Ohio J. Sci., vol. 39, pp. 239-249.

*1940*

Early embryonic somatic movements in birds and in mammals other than man. Monographs of the Society for Research in Child Development, vol. 5, no. 2, serial no. 25, 48 pp. Pub. by National Research Council, Washington, D. C.

Motion pictures of the behavior of young pouch opossums. (With D. S. Pankratz.) (Abstract.) Anat. Rec., vol. 76, suppl., no. 2, p. 84.

*1941*

Clarence Luther Herrick as teacher and friend. J. Comp. Neur., vol. 74, pp. 39-42.

*1943*

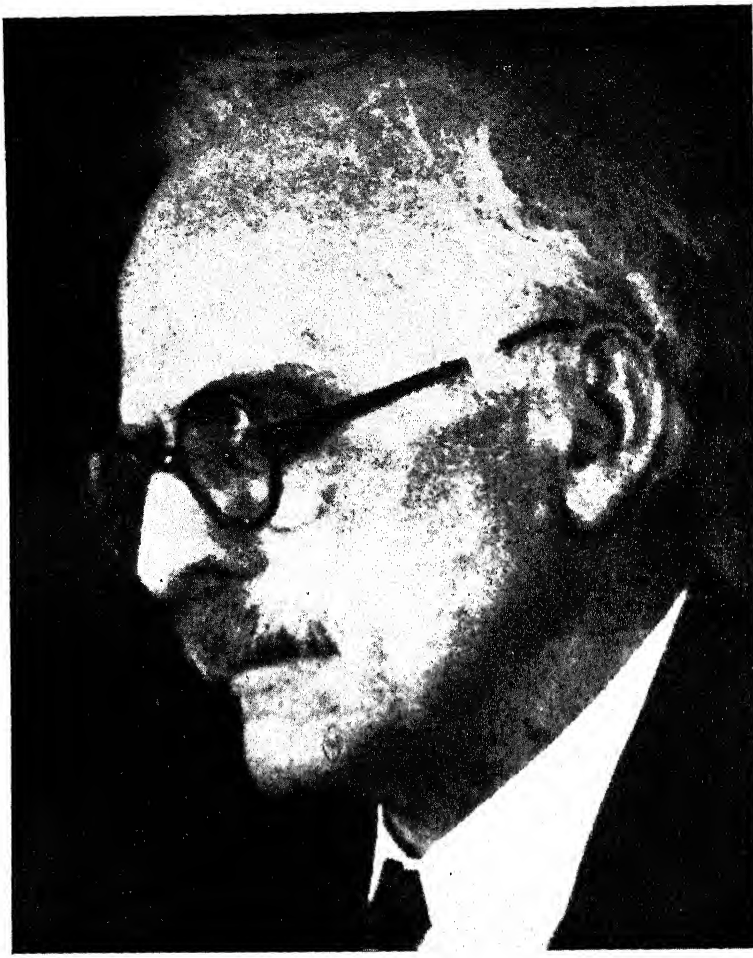
Periodicity in the development of the threshold of tactile stimulation in Amblystoma. (With R. W. Watkins.) J. Comp. Neur., vol. 78, no. 2, pp. 91-111.

## ADDENDUM

The following title appears in Doctor Coghill's own manuscript bibliography, accompanied by a carbon copy:

Flexion spasms and mass reflexes in relation to the ontogenetic development of behavior. Festschrift in honor of Prof. A. I. Heymanovich, U. S. S. R.

This paper was prepared for publication in Russia in 1933 or 1934, but a reference has been unobtainable. The complete paper will appear shortly in the Journal of Comparative Neurology.



Heber D. Curtis

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—THIRTEENTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# HEBER DOUST CURTIS

1872–1942

BY

ROBERT G. AITKEN

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1942

# HEBER DOUST CURTIS

## 1872–1942

BY ROBERT G. AITKEN

"Call Dr. Curtis!"—It was gray dawn of a raw December morning on Mount Hamilton, thirty years ago, and our eldest son, home from the university for his Christmas vacation, had roused us, his face drawn and distorted by the agonizing pain in his right abdomen. A word to our physician in San José had brought the curt order, "Bring the boy down at once. There's no time to lose. It's probably acute appendicitis."

By the time the boy and I were ready for the trip, Dr. Curtis had his automobile at the door and we were off on the three and one-half hour trip over the half-frozen, adobe mud road to San José. Surgeon and operating room were ready, and as soon as was humanly possible a highly inflamed appendix, just ready to burst, had been safely removed, and a relieved boy was coming peacefully out from the influence of the anesthetic.

Then Dr. Curtis, having first telephoned to the Lick Observatory to find out if he could do any town errands for anyone "at the top", started cheerfully back on his long, lonesome drive to the mountain, happy in the thought that he had once again been able to be of service.

I tell this story at the beginning of my sketch of the career of Dr. Curtis, to emphasize as strongly as possible the dominant trait of his character—his love for his fellow man, his eagerness to be of service. In our little semi-isolated community of thirty-five or forty adults we all stood ready to help each other in every respect, and I could have called on others who had automobiles and lived nearer to me, but in an emergency of any kind *it was the natural thing to call first on Dr. Curtis.* He was pre-eminently the Good Neighbor.

Born in Muskegon, Michigan, on June 27, 1872, Heber Doust Curtis, the elder son of Blair Curtis and Sarah Eliza (Doust) Curtis, could trace his American ancestry on his father's side through ten generations. A Union soldier, his

father had lost his left arm at Fredericksburg, and then, after taking his A.B. degree at the University of Michigan, had been successively, a school teacher, an editor and a United States Customs official. His mother was born in Maidstone, England, the daughter of a Methodist clergyman, but came to this country as a child and was educated at Albion Female Seminary where she took special interest in English literature and music. She reared her two boys, Heber and Walter, rather strictly. Dancing, card playing, and the theatre were frowned on, and she kept the boys at home of evenings by reading aloud with them the best books she could obtain. Otherwise, they lived the normal life of boys of their social class both at Muskegon and at Detroit where they took up their residence when Heber was seven years old.

He was a good student, finding no difficulty in maintaining a very high rank in his studies both in the grade schools and the Detroit High School. He had plenty of time for outdoor sports and took special pleasure in football, which he continued to play even after he became a teacher. Like many another American boy, he also took a keen interest in machine tools and, in fact, built his own lathe before he could afford to buy a standard one.

At the Detroit High School he took the straight classical course and displayed special aptitude for languages. He was "good", too, in mathematics, but, strangely enough, manifested no interest in the natural sciences, simply taking the courses required of him. Graduating with high standing, he entered the University of Michigan in 1889 and completed the requirements for the A.B. degree, with Phi Beta Kappa rank, in three years and took his A.M. degree in 1893.

When he entered the university, Curtis had decided to become a teacher of the classical languages. He therefore took all the courses in Latin and Greek that were offered, and, in addition, two years of Hebrew, two of Sanskrit, and one of Assyrian. He also enjoyed his work in mathematics, but, as in high school days, showed little interest in the sciences, and, so far as is known, never even entered the observatory which has trained so many American astronomers, including Campbell

and Hussey whom he was to join at the Lick Observatory a few years later.

Leaving the university, Curtis taught Latin at the Detroit High School for six months and then accepted a position as Professor of Latin and Greek at Napa College, a small Methodist institution in California. This proved to be a fateful decision, for here he found a small Clark refracting telescope, standing practically idle and on some impulse was moved to investigate it.

That really marked the beginning of his astronomical career, for while he continued to teach Latin and Greek at Napa for two years, and for another year at San José when Napa College merged with the University (now College) of the Pacific, he was giving more and more time to the study of astronomy. At the University of the Pacific, as at Napa College, he found a small observatory equipped with a good Clark 6-inch refractor and a standard reversible Coast Survey transit instrument. At the end of his first year at San José the professorship of mathematics and astronomy at the little institution became vacant and Curtis applied for it and was appointed!

This "switch", as he himself called it, from the classics to astronomy was one that probably could have happened only in a small college half a century ago. And it is probably the only case on record of a man giving up a career for which he had received full university training, and taking up another in which he had had no training at all except what he had acquired by his own reading and experience, and making the latter a brilliant success. Curtis, it is true, supplemented his own reading by spending the long summer vacation in 1898 at the Lick Observatory, but that was after he had accepted his new position.

In 1900, he was offered a Vanderbilt Fellowship at the University of Virginia and spent the next two years there, taking his Ph.D. degree in 1902, his thesis subject being "The Definitive Orbit of Comet 1898 I." Again, I know of no other astronomer who received his Ph.D. degree after no university training in his special field prior to his two years of fellowship work.

The move to Virginia involved financial problems for the fellowship stipend was only $350 a year, and he had married Mary D. Raper of Ann Arbor in 1895 and now had a family of two small children. In other respects, however, it was a fortunate one and was made at a fortunate time, for it permitted him to join the Lick Observatory Eclipse Expedition to Thomaston, Georgia, in 1900 and the United States Naval Observatory Expedition to Solok, Sumatra in 1901, as volunteer assistant.

His ability and resourcefulness in helping to set up, test and use the eclipse apparatus made so strong an impression upon Dr. Campbell, who headed the Georgia expedition, that he promptly invited Curtis to come to the Lick Observatory as an assistant as soon as he had secured his degree. Curtis himself was so fascinated by the work that in later years he took every opportunity to attend eclipse expeditions and was, in fact, member or leader of eleven in all, before his death. He often lamented, in his last years, that illness by keeping him from observing the eclipse of 1937, had made it impossible to round the number out to an even dozen.

In 1902 he took up residence on Mount Hamilton as assistant in the Lick Observatory and the next eighteen years were the most productive of his very active career. "Research work at Lick Observatory," he wrote in later years, "was, and still is, a very wonderful thing and it looked like a new world to me." His duty as assistant was to take part in the great program of the determination of the radial velocities of the brighter stars which Dr. Campbell had initiated a few years earlier and he set about it with such enthusiasm, mastering all details of spectroscopic observation and measurement, that his work was soon on a level with that of the best observers.

But he did not limit himself to radial velocity work. His eager, active mind led him to examine all the instruments at the observatory, to make suggestions for improvements in some of them and to compute orbits of comets and of spectroscopic binary stars. In 1905, he went to Cartwright, Labrador, with the unsuccessful expedition to observe the eclipse of the sun.

In 1906, he was asked to go to Santiago, Chile, to take charge

of the station established there a few years earlier for the purpose of extending to the south pole of the heavens Dr. Campbell's program of measuring the radial velocities of the brighter stars. This was an assignment that suited Curtis in every respect for it added zest to his astronomical work, and gave him an opportunity to master the Spanish language and to familiarize himself with the manners and customs of the Chilean people. He threw himself into his new work with his accustomed ardor, secured an excellent set of photographs of Morehouse's remarkable Comet of 1908 and made a notable addition to the great radial velocity observing program by the number of plates secured, the discovery of additional spectroscopic binary stars and the computation of orbits, and found time for making improvements in the mounting of the great reflector.

Dr. Campbell recalled him from Chile in 1910, to take full charge of the Crossley reflecting telescope and to carry on the program of nebular observations which had been so brilliantly begun by the late Dr. Keeler in 1898.

During the next ten years Curtis made his greatest contribution to astronomy. Nominally, it is true, he was simply carrying forward Keeler's program. Practically, it was his own program. The general subject was the same but the observing methods were Curtis's own, and there had been so many changes and improvements in the mounting, many of the most important by Curtis himself, that the Crossley reflector had become almost a new telescope.

The results of his work are embodied in "the Nebular Volume," Volume XI of the Publications of the Lick Observatory as well as in many short papers in various journals, and were afterwards included in his general memoir on the *Nebulae*, written for *Das Handbuch der Astrophysik*. The memoir on the *Planetary Nebulae*, with its beautiful photographs and drawings and detailed descriptions is a classic and the chapter on the spirals was even more important.

At that time (1910-20), astronomers in general had abandoned the conception of a plurality of worlds which had prevailed a century earlier, in favor of the idea that all the objects

revealed to us by our most powerful telescopes were members of a single great system. Curtis was led to take the older view on the basis of his own observations and of his study of the work of others. The dark areas and the great rift in the Milky Way would, he thought, if viewed from a sufficiently great distance, give much the appearance of a "banded spiral" of which he photographed many with the Crossley, and both phenomena could well be explained by the presence of a light-absorbing medium. This medium, too, would quite fully account for the fact that few spirals are visible to us near the plane of the Milky Way. They are there, but hidden by the light-absorbing cloud. Then, if the novae which Ritchie at Mount Wilson, he himself at the Lick, and other astronomers were beginning to find in increasing numbers in spiral nebulae were similar objects to the Milky Way novae, their relative faintness would give an approximate value for the distance of the spiral in which they appeared.

For a time only his colleagues at Mount Hamilton, and a few other astronomers agreed with him in his views. This did not greatly disturb Curtis. He was rather slow in formulating his opinions, but when once he had reached his conclusion he held to his views tenaciously and was always ready to defend them. It must have been a great satisfaction, however, to have Hubble's* researches in 1925, made with the 100-inch telescope and the far more accurate method of measuring distances to the nebulae provided by the Cepheid variable stars not only confirm his views as to the abundance of external galaxies and their great distances, but prove that his own figures had been extremely conservative.

In 1920, just as his observing program on the nebulae had reached a certain terminal point, he was invited to become director of the Allegheny Observatory and after some hesitation accepted the offer. This meant a radical change in the nature of his activities. He had first of all to settle some difficult administrative problems and then to devote some time to teaching at the University of Pittsburgh. Moreover, the 30-inch

*And those of other astronomers, later.

photographic refractor at Allegheny was specially planned for stellar parallax work in which he had had no experience. The program had been initiated by Professor Schlesinger, who had resigned the directorship to take up similar work as director of the Yale University Observatory.

Curtis, wisely, continued this program, and took a personal part in the actual observing work, but he contributed nothing new to it. His personal energies were devoted rather to building up the machine shop and to the design and construction of new instruments for his own observatory and for other institutions.

Characteristically, his first task was the grinding out of the periodic error in the driving worm of the 30-inch refractor. He designed and built a new type of stellar comparator, and a number of instruments for use on the four eclipse expeditions conducted jointly with his friend Dr. John A. Miller, director of the Sproul Observatory. A long-screw measuring machine which he built for Dr. Miller gave him special satisfaction for, as Dr. McMath has said, he regarded a successful ruling engine as the most perfect man-made machine.

Under his wise administration the great parallax program and the lesser programs of observing work made steady progress; his teaching work at the university was in a high degree successful; he was in constant demand as a lecturer and the eclipse expeditions and the design of improved instruments at the machine shop absorbed his surplus energies. He was advancing the interests of astronomy in many ways, even though he was not developing an observing program of his own, and he was happy in his relations with his colleagues at the university and observatory.

Then came the invitation to go to Michigan as the director of the observatory, coupled with the assurance that funds would be provided for building a large reflecting telescope. This was in 1930. It was the opportunity offered to build a great telescope that led him to accept the invitation. In other respects the directorship there offered little that he did not already have at Allegheny. But Curtis, like all astronomers who have worked with large telescopes, had problems in mind that could

be attacked successfully only with a very powerful instrument, and, in addition, had given much attention to the mounting of such a telescope and had quite definite ideas on the subject which he was eager to try out.

Unfortunately, the great depression followed. The disk of pyrex glass, large enough for the construction of a mirror of 97½-inch aperture, was successfully cast by the Corning Glass Company, and delivered to the observatory at Ann Arbor. But then the generous donor, Mr. Thomas W. Lamont, had to notify the university authorities that he could not go on with the enterprise!

This was a severe disappointment to Curtis, who was already absorbed in working out the details for the mounting of the telescope, but there was nothing he could do about it. He took up the general duties of his office, forwarded the various observing programs he found in progress and took a personal part in the actual observing work, gave regular lectures at the university, and put in his spare time in completing his working drawings, in the hope that funds for the great telescope might later become available.

Fortunately, when Curtis came to Ann Arbor, the development of the McMath-Hulbert Observatory as a private institution was well under way. As this gradually grew into the present powerful equipment for solar research, and became an integral part of the "Observatories of the University of Michigan," Curtis's interest in the project grew. He was in almost daily conference with Dr. Robert McMath, the active head of the observatory, throughout the last ten years of his life and Dr. McMath has testified that "his contributions to the McMath-Hulbert Observatory cannot be measured."

With all these varied duties, Dr. Curtis still found time to attend meetings of scientific societies, and to organize and head the successful eclipse expedition to Fryeburg, Maine, in 1932. His work in later years was interrupted by several periods of illness but despite these he was able to continue in active service to the very end of his life. After driving home from Cleveland, Ohio, where he had attended and taken an active part in the meeting of the American Astronomical Society during convo-

cation week (less than two weeks before his death) he complained of fatigue, but even on the day before his death he spent a few hours at his office. He died quietly in his sleep in the early morning of January 9, 1942.

Dr. Curtis was, of course, a member and officer of the professional astronomical societies of the country, serving as a member of the publication committee of the Astronomical Society of the Pacific for a number of years and as its president in 1912; a member of the council of the American Astronomical Society for several terms and vice-president of the Society in 1926; and vice-president and chairman, Section D (Astronomy) of the American Association for the Advancement of Science (1924). In recognition of his contributions to astronomy, he was elected a foreign associate of the Royal Astronomical Society of London and to membership in the National Academy of Sciences and in the American Philosophical Society. He also joined the Astronomische Gesellschaft in the earlier part of his career, and was a member of the International Astronomical Union, Commission 13 of solar eclipses.

He attended the meetings of the societies in our own country as regularly as possible and took an active part in their council meetings as well as in the discussions at the open sessions.

He had a remarkably wide range of intellectual interests combined with a passion for thoroughness in all work he undertook. This unusual combination made it possible for him to be at one and the same time a great linguist, a most successful teacher, a distinguished research observer, and a builder of instruments of precision. But his colleagues, students and friends will recall most of all his ever-cheerful comradeship, his wise counsel, his helpfulness in times of need. He was first of all a man who loved his fellow men and joyed in serving them.

University of Michigan
College of Literature, Science and the Arts
Faculty Record

Name: *Heber Doust Curtis*

Department: Astronomy

1. Date and Place of Birth: June 27, 1872, Muskegon, Michigan
2. Educational Record (Institution, Date, Degree):

Undergraduate Work: University of Michigan, A.B., 1892

Graduate Work: University of Michigan, A.M., 1893; University of Virginia, Ph.D., 1902

3. Academic and Professional Record at Institutions Other than University of Michigan:

Teacher, Detroit High School, 1893-94

Professor, Greek and Latin, Napa College (Calif.), 1894-96

Professor, Mathematics and Astronomy, College of the Pacific, 1896-1900

Vanderbilt Fellow in Astronomy, University of Virginia, 1900-02

Asst. and Asst. Astronomer, Lick Observatory, 1902-05

Acting Astronomer, in charge D. O. Mills Expedition to Southern Hemisphere (Santiago, Chile), 1906-10.

Astronomer, Lick Observatory, 1911-20

Director, Allegheny Observatory, 1920-30

Director and Professor of Astronomy, Univ. of Mich., 1930-42

Director Emeritus, Univ. of Mich., 1942

4. Membership in Professional and Learned Societies:

Astronomical Society of the Pacific (President, 1912)

American Association for the Advancement of Science (vice-president, Section D, Astronomy, 1924)

American Astronomical Society (vice-president, 1926)

Astronomische Gesellschaft

National Academy of Sciences

American Philosophical Society

Research Club (Univ. of Mich.)

Foreign Associate, Royal Astronomical Society

International Astronomical Union; member of Commission 13 of solar eclipses

Phi Beta Kappa; Sigma Xi; Phi Kappa Phi

## COMPLETE PROFESSIONAL BIBLIOGRAPHY

Note: Following the procedure of numerous scientific yearbooks, the media in which many papers have been published have been abbreviated as follows in the list below:

AJ—The Astronomical Journal
AN—Astronomische Nachrichten
AphJ—Astrophysical Journal
ASP—Publications of the Astronomical Society of the Pacific
LOB—Lick Observatory Bulletins
PopAstr—Popular Astronomy
PublAO—Publications of the Allegheny Observatory
PublMO—Publications of the Observatory of the University of Michigan
PublLick—Publications of Lick Observatory
Other media have been given in full, or slightly abbreviated.

### A. Scientific Papers

*1896*

Bright meteor observed at Napa. February 2, 1896. ASP *8*, 86.

*1898*

Latitude work with the Fauth transit instrument of the Lick Observatory. ASP *10*, 69.

Very bright meteor, March 4, 1898. ASP *10*, 79.

The Leonids in 1898. ASP *10*, 242.

*1899*

Elliptic Elements of Comet 1898 *b*. ASP *11*, 80. Also in AJ *19*, 195.

*1901*

The U. S. Naval Observatory eclipse expedition to Sumatra. ASP *13*, 205-213.

Observations of Eros, made with the 26-inch refractor of the Leander McCormick Observatory of the University of Virginia. AJ *21*, 117-8.

On the limits of unaided vision. LOB *2*, 67-9. Also in Science, *17*, 1010-1, 1903.

*1902*

Definitive determination of the orbit of Comet 1898 I. Astronomische Abhandlungen der AN, *1* no. 3; 35 pp. Abstract in ASP *14*, 127-31.

*1903*

Visual observations of the spectrum of Nova Geminorum made with the 36-inch refractor. LOB *2*, 132; also, ASP *15*, 222-3, and AphJ *19*, 83, 1904.

The spectrum of Nova Geminorum (with H. M. Reese). LOB *2*, 59-66; ASP *15*, 164.

Observation of the spectrum of Comet Borelly made with the thirty-six inch refractor. LOB *2*, 129.

A list of five stars whose velocities in the line of sight are variable (with W. W. Campbell). LOB *2*, 126; also in AphJ *18*, 306-8.

*1904*

A brief review of recent progress in solar physics. ASP *16*, 133-41.

Definitive orbit of the spectroscopic binary. ι Pegasi. LOB *2*, 169-73; also AphJ *19*, 212-9; abstract in ASP *16*, 117-8.

*1905*

On the radial velocities of Polaris, η Piscium, ε Aurigae, and β Orionis (with W. W. Campbell), LOB *3*, 86-7; also AphJ *21*, 191-3.

A list of nine stars whose radial velocities vary (with W. W. Campbell). LOB *3*, 84-86; also AphJ *21*, 185-90.

The quadruple system of Alpha Geminorum (paper given before AAS, December, 1904). Abstract in Science *21*, 419-20. Cf. also AAS Publ. *1*, 224-6, 1910.

The Lick Observatory-Crocker eclipse expedition to Labrador. ASP *17*, 173-81.

*1906*

The system of Castor. LOB *4*, 55-66; also in AphJ *23*, 351-69. Abstract in ASP *18*, 132-34.

First catalogue of spectroscopic binaries (with W. W. Campbell). LOB *3*, 136-46; abstract in ASP *18*, 62-66.

*1907*

Temperature control for silvered specula. LOB *4*, 158-60; also AphJ *26*, 256-62.

Recent changes at the Observatory of the D. O. Mills Expedition. ASP *19*, 227-33.

Orbit of the spectroscopic binary α Pavonis. LOB *4*, 154-5; also AphJ *26*, 274-6; abstract in ASP *19*, 259-60.

Orbit of the spectroscopic binary ϑ Draconis. LOB *4*, 156-8; also AphJ *26*, 263-7.

Orbit of the spectroscopic binary κ Velorum. LOB *4*, 155-6; also AphJ *26*, 271-3.

*1908*

Methods of determining the orbits of spectroscopic binaries. ASP *20*, 133-55.

*1909*

The variable radical velocity of κ Centauri LOB *5*, 178.

Three stars of great radial velocity, LOB *5*, 133-4. (Also given as paper before the AAS in August, 1909.) Abstract in Science *30*, 732-3.

Thirteen stars having variable radial velocities. LOB *5*, 139-40. (Paper given before AAS in Aug., 1909.) Abstracts in Science *30*, 733 and ASP *21*, 210.

Spectrographic and photographic observations of Comet 1908 *c* (Morehouse). LOB *5*, 135-8. Abstracts in Science *30*, 732-3 and ASP *21*, 208-10.

Recent progress in the work of the D. O. Mills Expedition to the Southern Hemisphere. ASP *21*, 199-201.

Position observations of Comet Halley. LOB *5*, 165.

Photographische Beobachtungen des Halleyschen Kometen 1909 *c*. AN *182*, 227.

Observations of Halley's Comet. ASP *21*, 211.

Definitive orbit of Comet 1898 VI (with L. S. Richardson). AN *182*, 337-358.

Astronomical problems of the southern hemisphere. ASP *21*, 231-44; Smith. Inst. Report 1910, 329-340.

*1910*

Photographs of Halley's Comet made at the Lick Observatory. ASP *22*, 117-130.

Observations of Comet 1910 *a*, made with the Crossley Reflector. LOB *5*, 181.

Note on photographs of Halley's Comet. LOB *5*, 183.

Notes on Halley's Comet. ASP *21*, 259-261, 1909, and *22*, 96-97, 1910.

The Lick Observatory photographs of Halley's Comet. Science *32*, 877.

Halley's Comet. ASP *22*, 33.

Comet 1910 *a*. ASP *22*, 33.

Changes in the mounting of the Crossley Reflector. ASP *22*, 40-41.

Velocidades radiales de estrellas con grandes movimientos propios (also in English). Vol. VI, Trabajos del Cuarto Congreso Cientifico. (1° Pan-americano) Santiago, Chile, 181-186.

Estrellas dobles australes decubiertas en el espectroscopio por el Observatorio de la D. O. Mills Expedición (also in English). Vol. VI, Trabajos del Cuarto Congreso Cientifico. (1° Pan-americano) Santiago, Chile, 176-180.

Problemas astronómicos del hemisferio austral (also in English). Vol. VI, Trabajos del Cuarto Congreso Cientifico (1° Pan-americano) Santiago, Chile, pp. 154-175.

*1911*

The theory of relativity. ASP *23*, 219-229.

Recent photographs of Comet Halley. PopAstr *19*, 451-2.

Photographic positions of Nova Lacertae. LOB *6*, 99.

Observations of Halley's Comet, 1909 *c*. AN *188*, 313-4.

Note on the object photographed by Sr. Comas Solá. AN *186*, 424.

The new star in Lacerta. ASP *23*, 50,

Methods of silvering mirrors. ASP *23*, 13-32; PopAstr *19*, 327-37 and 398-406.

Comet notes. ASP *23*, 267-69.

*1912*

Three interesting spiral nebulae. ASP *24*, 227-8; PopAstr *20*, 637; Journ. RAS Can *6*, 374-5.
Note on the planetary nebulae. ASP *24*, 195-97.
Note on R Cygni. Month. Not. RAS *73*, 92.
Descriptions of 132 nebulae and clusters photographed with the Crossley Reflector. LOB *7*, 81-84; abstract in Nature *90*, 341.

*1913*

The unit of stellar distance. ASP *25*, 213-15. Correction in ASP *25*, 266.
Search for asteroid 1911 MT(719), Albert. LOB *8*, 47-8.
Note on the Gegenschein. ASP *25*, 260-63.
The influence of gravitation on light. ASP *25*, 77-81.
Crossley Reflector improvements. ASP *25*, 265-66.
Descriptions of 109 nebulae and clusters photographed with the Crossley Reflector. LOB *8*, 43-46.

*1914*

Preliminary note on nebular proper motions. (Paper before National Academy of Sciences, December, 1914.) Abstract in Proc. Nat. Acad. Sc. *1*, 10-12, 1915; Science *40*, 770-71, 1914.
The Lick Observatory-Crocker eclipse expedition to Brovary, Russia (with W. W. Campbell). ASP *26*, 225-37; PopAstr *23*, 1-11, 1915.
Improvements in the Crossley mounting. ASP *26*, 46-51.

*1915*

Search for faint members of the Taurus Cluster. ASP *27*, 243.
Proper motions of the nebulae. ASP *27*, 214-18.
Note on Hind's variable nebula. ASP *27*, 242-43.

*1916*

Forms of planetary nebulae. (Paper before AAS, August.) Abstracts in PopAstr *24*, 658, and ASP *28*, 190.

*1917*

Note on the planetary nebulae. ASP *29*, 52-54.
Three novae in spiral nebulae. LOB 9, 108-10.
Novae in the spiral nebulae and the island universe theory. ASP *29*, 206-7.
New stars in spiral nebulae. ASP *29*, 180-82.
Finding list for General Catalogue numbers. ASP *29*, 180.
Absorption effects in the spiral nebulae. Proc. Nat. Acad. Sc. *3*, 678-82.

*1918*

Dark nebulae. ASP *30*, 65-7.
Nebular proper motions. (Paper before AAS, August.) Abstracts in AAS publ. *3*, 119-20, and PopAstr *33*, 599-600, 1915.
A spiral nebula in the Milky Way. ASP *30*, 161.

On the number of spiral nebulae. Amer. Phil. Soc. Proc. *57*, 512-20.
The number of the spiral nebulae. ASP *30*, 159-61. Copied in part in Observatory *41*, 390-91.

*1919*

Three new planetary nebulae. ASP *31*, 285.
Note on the result of the search for intra-Mercurial planets, eclipse of June 8, 1918. ASP *31*, 234-5.
Note on the nebulosity surrounding Nova Persei. LOB *10*, 35.
A contrast in stellar distribution ASP *31*, 223.
Modern theories of the spiral nebulae (paper before Washington Academy of Sciences, March). Abstracts in Proc. Wash. Acad. Sc. *9*, 219-227, and Journ. RAS Can. *14*, 317-327.

*1921*

The scale of the universe. Bull. Nat. Research Council *2*, 171-217.

*1922*

Stellar luminosities. ASP *34*, 33-39; Journ. RAS Can. *16*, 209-17.
Résumé of results bearing on the absolute magnitudes of the stars (paper before AAS, December, 1921). Abstracts in PopAstr *30*, 107, and in Publ. AAS *4*, 309, 1923.

*1923*

On irregularities in the velocity curves of spectroscopic binaries. Proc. Nat. Acad. Sc. *9*, 187-91.
Photographic adjustment of the equatorial. PopAstr *31*, 11-14.
Report of the eclipse committee, American Astronomical Society (H. D. Curtis, Chairman). Publ AAS *4*, 196-97.

*1924*

Les nebuleuses spirales et la constitution de l'univers (also in English). Scientia *35*, 1-9.

*1925*

Infra-red flash and coronal spectra, eclipse of January 24, 1925 (with Keivin Burns). PublAO *6*, 95-103.

*1928*

Light-year versus parsec. Nature, *121*, 789.
Two laboratory arcs. Journ. Opt. Soc. Amer. *18*, 697-700.

*1929*

A new type of comparator. PublAO *8*, 15-17. Abstracts in PopAstr *38*, 402, 1930; Publ AAS *8*, 340, 1931.
A set of permanent parallax sectors. PublAO *8*, 23-25.

*1931*

Interference in the solar corona (with W. R. Wright). Publ. Sproul Obs., Swarthmore College, No. 11. Journ. Opt. Soc. Amer. *21*, 154-70.

*1932*

The total solar eclipse of August 31, 1932 (University of Michigan Expedition). PopAstr *40*, 392.

*1935*

An ephemeris of 467 A.D. (with F. E. Robbins). Publ. Mich. Obs. *6*, 77-100, 1935. Republished in greater part as,—"The oldest known nautical almanac" in The Sky *5*, 8-9, 1940.

*1937*

The Lamont-Hussey Observatory. ASP *49*, 133-34.

*1939*

Navigation near the Pole. U. S. Naval Institute Proc. *65*, 1-9. Reprinted in The Polar Times, March.

*1940*

The new McGregor Building and 70-foot tower telescope of the McMath-Hulbert Observatory. PopAstr *48*, 348-52.

Reports of the Director of the Allegheny Observatory

| | | | | |
|---|---|---|---|---|
| 1922-23, | PopAstr | *32*, | 92-93, | 1924. |
| 1923-24, | " | *33*, | 18-19, | 1925. |
| 1925-26, | " | *35*, | 27-28, | 1927. |
| 1926-27, | " | *35*, | 561-62, | 1927. |
| 1927-28, | " | *37*, | 18-19, | 1929. |
| 1928-29, | " | *38*, | 147-48, | 1930. |
| 1929-30, | " | *39*, | 79-80, | 1931. |

Reports of the Director of the Observatories of the University of Michigan

| | | | | |
|---|---|---|---|---|
| 1930-31, | Publ AAS | *7*, | 68-9, | 1933. |
| 1931-32, | " | *7*, | 147-49, | 1933. |
| 1932-33, | " | *7*, | 253-57, | 1933. |
| 1933-34, | " | *8*, | 80-83, | 1934. |
| 1934-35, | " | *8*, | 180-3, | 1935. |
| 1935-36, | " | *8*, | 289-91, | 1936. |
| 1936-37, | " | *9*, | 69-74, | 1938. |

B. Monographs

*1918*

Descriptions of 762 nebulae and clusters photographed with the Crossley Reflector. PublLO, *31*, 1-42. 7 plates.

A study of occulting matter in the spiral nebulae. PublLO *13*, 43-54. 81 plates.

The planetary nebulae. PublLO *13*, 55-74. 80 plates.

*1933*

The nebulae. Bd V/2 of the Handbuch der Astrophysik, pp. 774-936, with 58 illustrations and 1 plate.

*1936*

Continuation of the above in the Ergänzungsband VII, pp. 546-563, with 1 figure.

C. Addresses; Papers of a General Nature

*1912*

A visit to Mt. Wilson. ASP *24*, 205-8.

Rosa Ursina, sive Sol; a retrospect. PopAstr *20*, 561-8.

The distances of the stars. ASP *23*, 143-163, 1911; reprinted in PopAstr *20*, 349-55; 430-42, 1912.

*1913*

Address of the retiring president of the Astronomical Society of the Pacific, in awarding the Bruce Medal to Professor J. C. Kapteyn. ASP *25*, 15-27.

*1915*

Astronomical exhibits at the Exposition. ASP *27*, 105-9.

*1917*

The nebulae. Fifth Adolfo Stahl Lecture of the ASP; San Francisco, March. ASP *29*, 91-103.

*1919*

Astronomical discovery. Sixth Adolfo Stahl Lecture of the ASP; San Francisco, ASP, The Adolfo Stahl Lectures in Astronomy. Stanford University Press.

Optical glass. ASP *31*, 77-85.

*1920*

Voyages to the moon. ASP *32*, 145-50.

*1923*

The influence of astronomy upon modern thought. Address at the dedication of the Porter Telescope at Cornell University, June 15, 1923. PopAstr *32*, 4-11, 1924.

*1925*

The equinox of 1950.0. Science *41*, 169-74, 1925. Address of retiring vice-president of Section D (Astronomy) of the American Association for the Advancement of Science.

*1928*

The unity of the universe. Journ. RAS Can *22*, 399-412, 1928. An address given at the meeting of the American Association for the Advancement of Science at Philadelphia in December, 1926.

*1929*

Religion from the Standpoint of Science, in "Religion and the Modern Mind," a book of composite authorship. Harper and Bros. New York, pp. 55-94.

*1931*

Modern Physical Science; its Relation to Religion, in "Has Science Discovered God?", a book of composite authorship. Crowell Co., New York, pp. 51-74.

*1934*

Eighty years of astronomy at the University of Michigan. Mich. Alumnus Quarterly *41*, 244-49.

*1935*

Address given at the dedication of the David Dunlap Observatory of the University of Toronto. Journ. RAS Can *29*, 277-8.

*1938*

The Comet-Seeker Hoax. PopAstr *46*, 71-75.

Receding horizons. Scient. Monthly *47*, 242-251. (Henry Russel Lecture for 1938.)

James Craig Watson, 1838-1880. Michigan Alumnus Quarterly, Summer, 1938.

*1941*

The dean of double-star workers. A biographical sketch of the work of Dr. R. G. Aitken. The Sky, *5*, 3-5.

D. Abstracts and Reviews

(Abstracts of Curtis's own papers are entered above under A; the following are on works by other authors)

*1903*

Publicationen des Astrophysikalischen Observatoriums Königstuhl-Heidelberg; Bd. I. ASP *15*, 233-35.

*1904*

On some results obtained by the D. O. Mills Expedition to the Southern Hemisphere (W. H. Wright). ASP *16*, 222.

*1909*

Two new calculating tables, J. Peters Neue Rechenafeln, and O. Lohse Tafeln für numerisches Rechnen mit Maschinen. ASP *21*, 226-7.

*1910*

Two new microscopes for the measurement of spectra (Zeitschrift für Instrumentenkunde, June, and Deutsche Mechaniker-Zeit, Nov. 15. ASP *23*, 67-8, 1911.

*1911*

Untersuchungen uber die Radialgeschwindigkeit des Sirius, von W. Munch, in AN *186*, 225-56. ASP *23*, 68-9.

Photographic determinations of stellar parallax, by F. Schlesinger, AphJ *32*, *33*, *34*, 1910 and 1911. ASP *23*, 205-6.

Permanency of pier construction. (Ueber Langeänderungen von Mauerwerk . . . von K. Scheel, AN *189* 230-4.) ASP *23*, 274-75.

Ueber die kosmogonische Stellung der Kometen, von E: Strömgren, Viertelj. der Astron. Gesellsch. *45*, 315, 1910. ASP *23*, 124-27.

Vorschlag zur Festlegung der photo. Gröszenskala, von E. Hertzsprung, AN *186*, 177-84, 1910. ASP *23*, 68.

Ueber den Einfluss der Schwerkraft auf die Ausbreitung des Lichtes, von A. Einstein, Ann. Phys. *35*, 898-908. ASP *23*, 272-73.

*1912*

Ueber das thermische Verhalten von gusseisernen Teilkreisen . . . von F. Göpel. Z. f. Instrumentenkunde *32*, 33-43. ASP *24*, 231.

Ein Modell zum Relativitätsprinzip, von H. Rohmann. Phys. Zeit. *12*, 1227-30, 1911. ASP *24*, 140.

The spectroscopic binary β Scorpionis, J. C. Duncan, Low. Obs Bull. *2*, 21-5. ASP *24*, 283-4.

On the distribution of brightness in the tail of Halley's Comet, Schwarzschild and Kron, AphJ *34*, 343-52, 1911. ASP *24*, 138-40.

Das Fernspektroscop, von H. Lehmann, Z. f. Instr. *32*, 1-6. ASP *24*, 140-41.

Nickeled glass reflectors for celestial photography, by R. W. Wood, AphJ *34*, 404-9, 1911. ASP *24*, 140.

Ueber . . . scheinbarer Durchmesser der Sterne . . ., von S. Pokrowsky, AN *192*, 21-36. ASP *24*, 284-85.

*1913*

Proper motions of telescopic stars, by G. C. Comstock, AJ *28*, 49-58. ASP *25*, 304-5.

Comet *a* 1910, by C. O. Lampland, Low. Obs. Bull. *2*, 34-55. ASP *25*, 304.

On the search for chlorophyll on the planets, by V. M. Arcichovsky, Ann. Inst. Mowocherkassk, *1*, no. 17, 1912. ASP *25*, 43-44.

Eine neue Form des . . . Interferometers . . ., von F. Goos, Z. f. Instr. *32*, 326-28, 1912. ASP *25*, 43.

Zur Frage . . . der Masse der Kometenkern . . . von S. Orloff. Bull. Acad. Imp. St. Petersb. No. 5,257. ASP *25*, 175-77.

Lehrbuch der spärischen Astronomie, von L. de Ball. ASP *25*, 224-25.

Das Bodeseche Gesetz und die sogenannten intramerkuriellen Planeten. von C. V. L. Charlier, AN *193*, 260-72. ASP *25*, 97-99.

Transactions of the astronomical observatory of Yale University, *2*, parts 3 and 4, 1912. ASP *25*, 44-46.

*1914*

Some results of observations with the photographic zenith tube, by F. E. Ross, AN *197*, 137-40. ASP *26*, 112-13.

Ein schwacher Begleiter zu Capella, von R. Furuhjelm, AN *197*, 181-82. ASP *26*, 113.

*1917*

Space, time and gravitation. Abstract of articles by de Sitter, Mon. Not. RAS *76*, 699-728, 1916; Observ. *39*, 412-19, 1916; and by T. J. J. See, Observ. *39*, 511-12, 1916. ASP *29*, 63-64; PopAstr *25*, 216-17.

Systematic variation . . . of stellar parallax, by A. S. Flint, AJ *29*, 189-204, 1916. ASP *29*, 61-2.

*1924*

Eclipses of the sun, by S. A. Mitchell, 1923. AphJ, *60*, 262-63.

E. Eclipse Expeditions

| *Year* | *Location* | *Sponsoring Institution* |
|---|---|---|
| 1900 | Thomaston, Georgia | Lick Observatory |
| 1901 | Solok, Sumatra | U. S. Naval Observatory |
| 1905 | Cartwright, Labrador | Lick Observatory |
| 1914 | Brovary, Russia | Lick Observatory |
| 1918 | Goldendale, Washington | Lick Observatory |
| 1923 | Yerbaniz, Mexico | Sproul Observatory |
| 1925 | New Haven, Conn. | Sproul Observatory |
| 1926 | Benkoelen, Sumatra | Sproul Observatory |
| 1929 | Takengon, Sumatra | Sproul Observatory |
| 1930 | Gerlach, Nevada | Allegheny Observatory |
| 1932 | Fryeburg, Maine | Univ. of Mich. Observatory |

Raymond Pearl.

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—FOURTEENTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# RAYMOND PEARL

1879–1940

BY

H. S. JENNINGS

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1942

# RAYMOND PEARL

## 1879–1940

BY H. S. JENNINGS

Raymond Pearl, Professor of Biology in the Medical School and in the School of Hygiene and Public Health of the Johns Hopkins University, died at Hershey, Pennsylvania, November 17, 1940, at the age of sixty-one years.

He was born at Farmington, New Hampshire, June 3, 1879. He came of a New England family of scholarly traditions, primarily in the classical direction. Earlier generations had included students of Greek and Latin, and it was the intention of Pearl's parents and grandparents that he should continue the family tradition in this respect. He attended school at Farmington; with two final years at the high school in Rochester, eight miles away, for the purpose of getting a better foundation in Greek and Latin. At the age of 16 he entered Dartmouth College, expecting to make the classics his chief field of study. During his first year he was more interested in the opportunities for free activity than in his studies; a fact which was reflected in the low grades which he received. But in that first year biology was a required subject, and this opened his eyes to what became his main interest. After the first week of the course in biology he consulted the instructor, John H. Gerould, as to whether he might, if he worked hard, go into biology rather than Greek. The change from classical to biological interests was a shock to his family, causing a rift that was long in healing. An account of Pearl in "Dartmouth '99",[1] speaks thus of his relation to biology: "The subject obsessed him. He talked, thought, studied and dreamed in terms of biology. He set himself an almost incredible standard of exactness and thoroughness. This standard he likewise unflinchingly demanded from all his students and associates, not excepting members of his own family in such ways as they shared his professional labors."

[1] A Thirty-fifth Report of the Class of 1899 of Dartmouth College. 1941. Book II: Good Companions All. R. Pearl (with portrait). This will be referred to as "Dartmouth '99."

He graduated from Dartmouth with the degree of A.B. in 1899. According to the Class Report before cited "Pearl was the youngest graduate in our class." During his senior year he was assistant in the course in general biology, of which the present writer was at that time in charge. He showed at that early period the masterful and competent personality that marked him throughout life.

But in his relations with the rest of the college his qualities of leadership were manifested mainly in relation to music,—at that time and throughout life his favorite avocation. As to this, certain paragraphs from the sketch in "Dartmouth '99", above quoted, present interesting pictures:

"He might be the first American to deliver the Heath Clark lectures at the University of London, or the most skillful juggler of the logistic curves of Verhulst; to us he was still the boy cornetist and the fellow who single handed conjured the first Dartmouth Band into existence out of rustic young neophytes and rusty and discarded tubas. He was our full-fledged impressario before we even knew there was such a word, and no crowd of urchins ever followed the Pied Piper of Hamelin so devotedly and gaily as we of '99 and all our Dartmouth contemporaries followed the imperious form of Pearl, as in corduroy or white duck trousers and with much 'windy suspiration of forced breath' he poured strange harmonies on the campus air." A member of his class gives (in the same publication) certain personal experiences: "Pearl had been talking to Joe and me trying to get us interested in some kind of a band instrument. Finally he dug up an alto horn for Joe and a battered old E-flat tuba for me. Where they came from God only knows. After working on them for a while we finally got the valves so they would work, and after that all Pearl had to do was to teach us how to finger the valves and teach us music, which was a tall order. He used to collar us and make us go up to the fraternity rooms (over Frost's jewelry store) and practice with him. After we got so we could play a few notes he used to make us march behind him around and around the billiard table."

All this is most characteristic, as will be recognized by those

who were associated with him in later life. Pearl never ceased to be propagandist for amateur musical performance. The account quoted above continues: "Ray became adept at almost every wind instrument. Even on the French horn, undertaken in middle life, and recognized as one of the most difficult of instruments, he became a proficient amateur. From boyhood to the latest gathering of Baltimore friends and wives at Hershey the night before he died, music had been a passion in Ray's life."

In the fall of 1899 Pearl went with me to the University of Michigan, where for three years he was assistant in zoology while at work as a graduate student. He took part in the Biological Survey of the Great Lakes, founded and led by the late Jacob Reighard, working on variation in fishes (1900 to 1902). He received at the University of Michigan in 1902 the degree of Doctor of Philosophy, at the age of twenty-three. From 1902 to 1906 he was Instructor in Zoology at the University of Michigan.

It was in the laboratory of the University of Michigan that he met Maud M. De Witt, who became his wife. She held at that time an important administrative place in the complex hierarchy of the large zoological laboratory. They were married in 1903. She accompanied him in study abroad during the years 1905 and 1906, when they worked at the University of London, the University of Leipzig, and at the Marine Biological Station at Naples. Mrs. Pearl later cooperated with him extensively in his scientific work, and at the time of his death was managing editor of the journal "Human Biology", and assistant editor of the "Quarterly Review of Biology"—the two journals founded and edited by Pearl.

Pearl published a number of contributions before receiving the doctorate. His dissertation was on the reactions and behavior of Planarians. He next contributed a series of papers on genetic problems in lower organisms. He then decided to enter the field of the application of statistical methods to biological problems and spent the year 1905-1906 at work with Karl Pearson at University College, London. During the same visit to Europe he worked also at Leipzig and at the Marine Biological

Station at Naples. While in London he finished and elaborated statistically a valuable piece of work on assortative mating in Protozoa. This he presented before the Royal Society of London; like many other contributions of Pearl it became a subject of controversy. He became in 1906 Associate Editor (with Pearson) of "Biometrika." But it was difficult for two such strong and aggressive personalities as Pearson and Pearl to work intimately together; there was a falling out, and the connection with "Biometrika" ceased in 1910. The two men remained friends, however: "there was a strong bond between them even if they did not agree on many subjects. They were in frequent correspondence", and after Pearson's death Pearl published (1936) an appreciative memoir of him.

Pearl returned to America in 1906, and was instructor in zoology at the University of Pennsylvania in 1906-1907. His contributions to biology were now mainly cast in the statistical mould. In 1907 he went to the University of Maine at Orono, as head of the department of biology of the Maine Agricultural Experiment Station, remaining there until 1918. During the years in Maine he made many contributions to the genetics and biology of the fowl and of other domestic animals, many of them published with his associate, F. M. Surface. In 1915 appeared two books. One was of a specialized character: a treatise on Diseases of Poultry, published with F. M. Surface and M. R. Curtis. The other was his first more general work on biological problems: a critical examination of methods of investigation, entitled "Modes of Research in Genetics." Use of mathematical methods was emphasized, and exemplified.

His work at the Maine Experiment Station showed a mastery of statistical methods, and an organizing ability such that on the entrance of the United States into the first World War he was called to Washington by Hoover to act as Chief of the Statistical Division of the newly organized United States Food Administration (1917-1919). He built up a large organization, which included a number of well-known men of science. During this period he published a number of papers on foods and prices; also a book on "The Nation's Food."

Early in 1918 Pearl was called, at the instance of Dr. William

Welch, to become Professor of Biometry and Vital Statistics in the newly founded School of Hygiene and Public Health of the Johns Hopkins University. He took up his work there in the fall of 1918. (While at Washington he was in 1917-18 on leave of absence from the Maine Agricultural Experiment Station. He was appointed at Johns Hopkins in 1918 but during the fall of that year he divided his time between the work at Washington and that at Baltimore. He was then sent to Europe on work of the Food Administration, and after his return continued to spend part of his time at Washington, part at Baltimore, until March 1, 1919, when he moved to Baltimore and devoted his full time to the University.) He organized at Johns Hopkins a department and laboratory of statistics, with Lowell J. Reed as associate professor; and gave courses in statistical methods and their application to biology and medicine.

Pearl remained at Johns Hopkins for the remainder of his life, though with some changes of work and title. It will be well at this point to note certain characteristics of the man and his work. He was a man of unusual height and weight, physically an impressive figure. His was a masterful personality, of extraordinary resourcefulness and initiative, of wide knowledge, astonishing power of work, remarkable versatility and scope, and strong ambitions. His interest in biology was encyclopedic. In his contributions he touched upon most aspects of the subject. This was not a matter of merely the extent of scattered interests, but rather of the kind of interest, and of the kind of man that he was. This has been best expressed by L. J. Henderson in his obituary notice in the American Philosophical Society's Yearbook for 1940:

"There are two kinds of men of science whose interests and activities greatly contrast. One kind, the orthodox, today very numerous, proceed by a kind of orthogenetical development and do not often step aside from a straight and narrow path. The other kind, rare today, though often met with three or even two centuries ago, feel that their intense interest in all things—their *philosophical* interest in an older sense of the word philosophical that has been preserved in the name of our Society—is a safe guide. Such a man was Francis Galton and another, in some measure a disciple of Galton's, was Raymond Pearl."

The breadth of Pearl's interests did not mean that his interest in particular subjects was weak. On the contrary his interest in any subject to which he gave his attention was so intense that at any given moment he might seem a partisan and propagandist of a particular field or method of biological science.

Among the seven hundred and twelve titles (including seventeen books) in the list of Pearl's writings hereto appended will be found contributions on the most varied fields or aspects of biology, or of human affairs as a division of biology. There are papers on animal behavior, from Protozoa to man; on general physiology; many on varied aspects of genetics (on variations, on abnormalities, on the breeding of Drosophila, of poultry, of cattle, of corn, of cantaloupes, on tongue colors in cattle, on the colors of hens' eggs, on the biology of sex, on the effects of parental alcoholism on progeny, on mutation, on methods of research in genetics, on the effect (or absence of effect) of selection, and on many other problems of genetics). There are many technical contributions on the care and breeding of fowls (fertility and fecundity in fowls, diseases of fowls, plumage patterns, egg production, keeping fowls free from lice, the folk-lore of hens' eggs, and the like). Many papers are devoted to technique, in the laboratory and in the field. There are extensive contributions to statistical methods, some abstruse, some directly practical. Many papers deal with disease: influenza, pneumonia, tuberculosis, cancer, encephalitis. Many papers (more than on any other subject) deal with the biology of man: papers on longevity and mortality, on the effects of alcohol and of tobacco, on eugenics, on race culture, on the biology of superiority, on the embryological basis of mortality, on infant mortality, on the biology of death, on population, on contraception, on the vitality of the peoples of America and of the peoples of England and Wales, on world overcrowding, on the biological effects of war, on the history of vital statistics, on patterns for living together. There are papers on food and prices, on wheat conservation, on "the nation's food", on food thrift, on business cycles. There are papers of philosophical import: on evolution and the origin of life, on "evolution and the Irish", on vegetarian biology, on the living machine, on the pragmatic stand-

Raymond Pearl.

NATIONAL ACADEMY OF SCIENCES
OF THE UNITED STATES OF AMERICA
BIOGRAPHICAL MEMOIRS
VOLUME XXII—FOURTEENTH MEMOIR

# BIOGRAPHICAL MEMOIR

OF

# RAYMOND PEARL

1879–1940

BY

H. S. JENNINGS

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1942

# RAYMOND PEARL

## 1879–1940

BY H. S. JENNINGS

Raymond Pearl, Professor of Biology in the Medical School and in the School of Hygiene and Public Health of the Johns Hopkins University, died at Hershey, Pennsylvania, November 17, 1940, at the age of sixty-one years.

He was born at Farmington, New Hampshire, June 3, 1879. He came of a New England family of scholarly traditions, primarily in the classical direction. Earlier generations had included students of Greek and Latin, and it was the intention of Pearl's parents and grandparents that he should continue the family tradition in this respect. He attended school at Farmington; with two final years at the high school in Rochester, eight miles away, for the purpose of getting a better foundation in Greek and Latin. At the age of 16 he entered Dartmouth College, expecting to make the classics his chief field of study. During his first year he was more interested in the opportunities for free activity than in his studies; a fact which was reflected in the low grades which he received. But in that first year biology was a required subject, and this opened his eyes to what became his main interest. After the first week of the course in biology he consulted the instructor, John H. Gerould, as to whether he might, if he worked hard, go into biology rather than Greek. The change from classical to biological interests was a shock to his family, causing a rift that was long in healing. An account of Pearl in "Dartmouth '99",[1] speaks thus of his relation to biology: "The subject obsessed him. He talked, thought, studied and dreamed in terms of biology. He set himself an almost incredible standard of exactness and thoroughness. This standard he likewise unflinchingly demanded from all his students and associates, not excepting members of his own family in such ways as they shared his professional labors."

[1] A Thirty-fifth Report of the Class of 1899 of Dartmouth College. 1941. Book II: Good Companions All. R. Pearl (with portrait). This will be referred to as "Dartmouth '99."

He graduated from Dartmouth with the degree of A.B. in 1899. According to the Class Report before cited "Pearl was the youngest graduate in our class." During his senior year he was assistant in the course in general biology, of which the present writer was at that time in charge. He showed at that early period the masterful and competent personality that marked him throughout life.

But in his relations with the rest of the college his qualities of leadership were manifested mainly in relation to music,—at that time and throughout life his favorite avocation. As to this, certain paragraphs from the sketch in "Dartmouth '99", above quoted, present interesting pictures:

"He might be the first American to deliver the Heath Clark lectures at the University of London, or the most skillful juggler of the logistic curves of Verhulst; to us he was still the boy cornetist and the fellow who single handed conjured the first Dartmouth Band into existence out of rustic young neophytes and rusty and discarded tubas. He was our full-fledged impressario before we even knew there was such a word, and no crowd of urchins ever followed the Pied Piper of Hamelin so devotedly and gaily as we of '99 and all our Dartmouth contemporaries followed the imperious form of Pearl, as in corduroy or white duck trousers and with much 'windy suspiration of forced breath' he poured strange harmonies on the campus air." A member of his class gives (in the same publication) certain personal experiences: "Pearl had been talking to Joe and me trying to get us interested in some kind of a band instrument. Finally he dug up an alto horn for Joe and a battered old E-flat tuba for me. Where they came from God only knows. After working on them for a while we finally got the valves so they would work, and after that all Pearl had to do was to teach us how to finger the valves and teach us music, which was a tall order. He used to collar us and make us go up to the fraternity rooms (over Frost's jewelry store) and practice with him. After we got so we could play a few notes he used to make us march behind him around and around the billiard table."

All this is most characteristic, as will be recognized by those

who were associated with him in later life. Pearl never ceased to be propagandist for amateur musical performance. The account quoted above continues: "Ray became adept at almost every wind instrument. Even on the French horn, undertaken in middle life, and recognized as one of the most difficult of instruments, he became a proficient amateur. From boyhood to the latest gathering of Baltimore friends and wives at Hershey the night before he died, music had been a passion in Ray's life."

In the fall of 1899 Pearl went with me to the University of Michigan, where for three years he was assistant in zoology while at work as a graduate student. He took part in the Biological Survey of the Great Lakes, founded and led by the late Jacob Reighard, working on variation in fishes (1900 to 1902). He received at the University of Michigan in 1902 the degree of Doctor of Philosophy, at the age of twenty-three. From 1902 to 1906 he was Instructor in Zoology at the University of Michigan.

It was in the laboratory of the University of Michigan that he met Maud M. De Witt, who became his wife. She held at that time an important administrative place in the complex hierarchy of the large zoological laboratory. They were married in 1903. She accompanied him in study abroad during the years 1905 and 1906, when they worked at the University of London, the University of Leipzig, and at the Marine Biological Station at Naples. Mrs. Pearl later cooperated with him extensively in his scientific work, and at the time of his death was managing editor of the journal "Human Biology", and assistant editor of the "Quarterly Review of Biology"—the two journals founded and edited by Pearl.

Pearl published a number of contributions before receiving the doctorate. His dissertation was on the reactions and behavior of Planarians. He next contributed a series of papers on genetic problems in lower organisms. He then decided to enter the field of the application of statistical methods to biological problems and spent the year 1905-1906 at work with Karl Pearson at University College, London. During the same visit to Europe he worked also at Leipzig and at the Marine Biological

Station at Naples. While in London he finished and elaborated statistically a valuable piece of work on assortative mating in Protozoa. This he presented before the Royal Society of London; like many other contributions of Pearl it became a subject of controversy. He became in 1906 Associate Editor (with Pearson) of "Biometrika." But it was difficult for two such strong and aggressive personalities as Pearson and Pearl to work intimately together; there was a falling out, and the connection with "Biometrika" ceased in 1910. The two men remained friends, however: "there was a strong bond between them even if they did not agree on many subjects. They were in frequent correspondence", and after Pearson's death Pearl published (1936) an appreciative memoir of him.

Pearl returned to America in 1906, and was instructor in zoology at the University of Pennsylvania in 1906-1907. His contributions to biology were now mainly cast in the statistical mould. In 1907 he went to the University of Maine at Orono, as head of the department of biology of the Maine Agricultural Experiment Station, remaining there until 1918. During the years in Maine he made many contributions to the genetics and biology of the fowl and of other domestic animals, many of them published with his associate, F. M. Surface. In 1915 appeared two books. One was of a specialized character: a treatise on Diseases of Poultry, published with F. M. Surface and M. R. Curtis. The other was his first more general work on biological problems: a critical examination of methods of investigation, entitled "Modes of Research in Genetics." Use of mathematical methods was emphasized, and exemplified.

His work at the Maine Experiment Station showed a mastery of statistical methods, and an organizing ability such that on the entrance of the United States into the first World War he was called to Washington by Hoover to act as Chief of the Statistical Division of the newly organized United States Food Administration (1917-1919). He built up a large organization, which included a number of well-known men of science. During this period he published a number of papers on foods and prices; also a book on "The Nation's Food."

Early in 1918 Pearl was called, at the instance of Dr. William

Welch, to become Professor of Biometry and Vital Statistics in the newly founded School of Hygiene and Public Health of the Johns Hopkins University. He took up his work there in the fall of 1918. (While at Washington he was in 1917-18 on leave of absence from the Maine Agricultural Experiment Station. He was appointed at Johns Hopkins in 1918 but during the fall of that year he divided his time between the work at Washington and that at Baltimore. He was then sent to Europe on work of the Food Administration, and after his return continued to spend part of his time at Washington, part at Baltimore, until March 1, 1919, when he moved to Baltimore and devoted his full time to the University.) He organized at Johns Hopkins a department and laboratory of statistics, with Lowell J. Reed as associate professor; and gave courses in statistical methods and their application to biology and medicine.

Pearl remained at Johns Hopkins for the remainder of his life, though with some changes of work and title. It will be well at this point to note certain characteristics of the man and his work. He was a man of unusual height and weight, physically an impressive figure. His was a masterful personality, of extraordinary resourcefulness and initiative, of wide knowledge, astonishing power of work, remarkable versatility and scope, and strong ambitions. His interest in biology was encyclopedic. In his contributions he touched upon most aspects of the subject. This was not a matter of merely the extent of scattered interests, but rather of the kind of interest, and of the kind of man that he was. This has been best expressed by L. J. Henderson in his obituary notice in the American Philosophical Society's Yearbook for 1940:

"There are two kinds of men of science whose interests and activities greatly contrast. One kind, the orthodox, today very numerous, proceed by a kind of orthogenetical development and do not often step aside from a straight and narrow path. The other kind, rare today, though often met with three or even two centuries ago, feel that their intense interest in all things—their *philosophical* interest in an older sense of the word philosophical that has been preserved in the name of our Society—is a safe guide. Such a man was Francis Galton and another, in some measure a disciple of Galton's, was Raymond Pearl."

The breadth of Pearl's interests did not mean that his interest in particular subjects was weak. On the contrary his interest in any subject to which he gave his attention was so intense that at any given moment he might seem a partisan and propagandist of a particular field or method of biological science.

Among the seven hundred and twelve titles (including seventeen books) in the list of Pearl's writings hereto appended will be found contributions on the most varied fields or aspects of biology, or of human affairs as a division of biology. There are papers on animal behavior, from Protozoa to man; on general physiology; many on varied aspects of genetics (on variations, on abnormalities, on the breeding of Drosophila, of poultry, of cattle, of corn, of cantaloupes, on tongue colors in cattle, on the colors of hens' eggs, on the biology of sex, on the effects of parental alcoholism on progeny, on mutation, on methods of research in genetics, on the effect (or absence of effect) of selection, and on many other problems of genetics). There are many technical contributions on the care and breeding of fowls (fertility and fecundity in fowls, diseases of fowls, plumage patterns, egg production, keeping fowls free from lice, the folk-lore of hens' eggs, and the like). Many papers are devoted to technique, in the laboratory and in the field. There are extensive contributions to statistical methods, some abstruse, some directly practical. Many papers deal with disease: influenza, pneumonia, tuberculosis, cancer, encephalitis. Many papers (more than on any other subject) deal with the biology of man: papers on longevity and mortality, on the effects of alcohol and of tobacco, on eugenics, on race culture, on the biology of superiority, on the embryological basis of mortality, on infant mortality, on the biology of death, on population, on contraception, on the vitality of the peoples of America and of the peoples of England and Wales, on world overcrowding, on the biological effects of war, on the history of vital statistics, on patterns for living together. There are papers on food and prices, on wheat conservation, on "the nation's food", on food thrift, on business cycles. There are papers of philosophical import: on evolution and the origin of life, on "evolution and the Irish", on vegetarian biology, on the living machine, on the pragmatic stand-

point in philosophy, on natural theology without theistic implications, on reconciling religion and Darwinism, on humanizing biology, on "a philosopher for the bloc", on skepticism reconciled, on "scientists into philosophers", on "America today and possibly tomorrow." There are many miscellaneous papers on the most varied subjects constituting a sort of journalism of science: on an eighteenth century patron of science, on "the prince of colyumists", on statistics of garbage collection, on a new statistical journal, on Jewish and Christian marriages, on the work of agricultural experiment stations, and the like.

The journals or other publications to which Pearl contributed in addition to the usual journals of research in zoology, genetics or physiology, make a long list, which may be classified as follows:

*Statistical journals:* Biometrika, Metron, Journal of the Royal Statistical Society, Publications of the American Statistical Association, Nordisk Statistisk Tidskrift.

*Medical journals:* Medicine, American Medicine, Journal of the American Medical Association, Archives of Internal Medicine, New York Medical Journal, British Medical Journal, Southern Medical Journal, Review of Tuberculosis, Public Health Reports, American Journal of Public Health, Archives of Pathology, International Clinics, Birth Control Review, Bulletin of the Institute of the History of Medicine, Milbank Memorial Quarterly, American Journal of Obstetrics and Gynecology.

*Agricultural journals:* Farm and Home, American Breeders' Magazine, Breeders' Gazette, American Veterinary Review, Farmers' Advocate, Farm and Fireside, Hoard's Dairyman, Bulletin of the Maine Agricultural Experiment Station, Farmers' Bulletin of the United States Department of Agriculture, Inland Poultry Journal, Poultry Science, Journal of Agricultural Research, Horseman and Spirit of the Times.

*Encyclopedias:* Britannica, Americana, of the Social Sciences.

*Miscellaneous scientific publications:* Eugenics Review, Popular Science Monthly, Scientific Monthly, American Anthropologist, Journal of Biological Chemistry, Popular Science, Annals of the American Academy of Political and Social Science, Geographical

Review, Nature, Natural History, American Speech, Botanical Gazette, Annals of Botany, American Journal of Physical Anthropology, Political Science Quarterly, Bulletin of the American Mathematical Society, Ecology, Science Digest, American Journal of Sociology, Scientia, Journal of Social Psychology, Wattenschappeliike Bladen.

*Literary and miscellaneous journals:* The Independent, the Dial, Saturday Review of Literature, The Nation, World's Work, Ladies Home Journal, Harper's Magazine, the Annalist, Readers' Digest, Literary Review, American Mercury, Time and Tide, School and Society, Johns Hopkins Alumni Magazine, Cosmopolitan, Yale Review.

*Newspapers:* The New York Times, New York Evening Post, Baltimore Evening Sun.

This is a remarkable record of publication. It may be questioned whether in America it has ever been equaled by a man of science, in extent and variety. For the forty-one years during which Pearl was active in publication the average number of titles per year is 17.3. In some single years there were more than thirty titles; in 1913 there were thirty-four. The bibliographic record is a sufficient witness to the breadth of Pearl's interests and to the activity of his mind.

Yet from these facts it is not to be inferred that he lacked strong leading interests. The contrary is decidedly the case. He was strongly and continuously interested in certain particular fields, and he deeply influenced them. What the record shows is that in addition to being an investigator, he was greatly interested in the dissemination and propagation of scientific knowledge. And further he was intensely interested in the large and goodly frame of things.

His leading biological interests and fields of work may be traced somewhat as follows:

In his early years (1900 to about 1904) Pearl, like many young men entering science, simply took hold wherever he saw opportunity. He published notes on laboratory technique, summary reviews of work in general physiology, and studies in animal behavior (this being, in the laboratory where he was, a very active subject). Soon he began to show a predilection

for genetics, publishing observations on variations and abnormalities.

With the period of his study of biometrics with Pearson (1905-1906) these latter subjects became his chief field of interest. At the same time he acquired a strong interest, which he never lost, in the methods of mathematical handling of biological data; to these he made throughout life many contributions. At about this period began also his primary interest in man as a biological organism; this was destined to become later his chief field of labor.

With his transfer to the Maine Agricultural Experiment Station (1907) the domestic fowl became his chief object of biological study. He dealt with the specialized problems which it presents (becoming an authority in practical poultry breeding), and also with the fundamental questions (particularly in genetics) which the fowl presents in common with other organisms. He continued also during this period (1907-1918) his contributions to the lines of work which he had earlier begun: to statistical methods, to variation and inheritance and to biological relations in the life of man. During this period also began or became much intensified his activity in the dissemination of biological knowledge; now through contributions to non-technical and non-scientific journals, such as the *Independent* and the *Dial.*

The years (1917-1919) during which he headed the statistical division of the United States Food Administration formed an interlude in which he acquired interest in some additional phases of the biology of man: in food, in war, in administration and business. He made contributions on these matters, which were unified by the fact that they appertained all to the particular biological organism in which Pearl was most interested.

With the transfer to Johns Hopkins (1919) came gradually a centralizing of all his interests in the biology of man. A break with past interests was reinforced by a fire which in 1919 destroyed his notes on past work, as well as his large library of reprints. During the organization of the statistical laboratory and of courses in the statistical treatment of biology and medicine there was naturally an accentuation of interest in the prob-

lems of method, evidenced by the publication in 1923 of his well known textbook "Introduction to Medical Biometry and Statistics." As Statistician of the Johns Hopkins Hospital (1919-1935) he systematized autopsy records and published at intervals data and conclusions based on study of these.

Soon his studies took a more experimental and broadly biological turn. Though they were henceforth directed mainly toward the biology of man, he employed other organisms for experimental purposes. He carried through extensive breeding and experimental studies on Drosophila, with relation to duration of life and its inheritance, mortality, and growth of populations; and on the factors, genetic and environmental, that influence these. They were accompanied by statistical investigations on the same kinds of problems in man.

Based on these various lines of work, Pearl published several series of articles and a number of books. In 1922 appeared a volume on "The Biology of Death", based on Lowell Lectures given in 1920. From 1922 to 1927 appeared his "Experimental Studies on the Duration of Life", based on the work on Drosophila. The results of these studies, with much other material, were embodied in his books on "The Biology of Population Growth" (1925) and on "The Rate of Living" (1928). An extensive statistical investigation of the effects of the use of alcohol on longevity and mortality, based on a great number of case histories collected by Pearl, was published in 1926 as a book under the title "Alcohol and Longevity." This investigation led him to the conclusion that the moderate consumption of alcohol is not harmful, and on this conclusion he based his own practice. These studies and conclusions were widely publicized, giving rise to controversy. A similar study made in later years (1938) on the effects of the use of tobacco led him to the conclusion that tobacco is harmful even in small quantities. This again attracted much attention in the press.

From 1920 on appeared a series of papers with L. J. Reed on Population Growth and Its Mathematical Representation, culminating in a curve of population growth, which was employed in forecasting the course of human population in future

periods. This, like much of Pearl's other work, aroused interest and controversy.

Other contributions to the biology of man dealt with the biological nature and classification of diseases, and with biological aspects of certain special diseases, notably tuberculosis, cancer, influenza, pneumonia, diseases of the heart, encephalitis. Many contributions, up to the last, deal with human reproduction; including a series of reports on the problems and results of birth control, based largely on the operations of a birth control clinic in Baltimore. A volume of collected papers on the biology of man, entitled "Studies in Human Biology" was published in 1924.

In 1923 Pearl received the title of Professor of Biology in the Medical School, a title which he retained to the end of his life. His associations at Johns Hopkins were throughout with the medical divisions of the University, rather than with the distantly located departments of zoology and botany in the "Philosophical" Division. In 1925 he gave up the direction of the work of the Department of Statistics and was succeeded there by Lowell J. Reed. In that year Pearl became director of the Institute for Biological Research, an enterprise maintained in connection with the Johns Hopkins University for five years by the Rockefeller Foundation. He was enabled to devote himself for this period entirely to research. He had during this time the title of Research Professor in the Johns Hopkins University. The Institute for Biological Research was not adjoined to any of the existing schools or departments of the University, but was an independent division of it.

At the end of the five year period, in 1930, Pearl was given the title of Professor of Biology in the School of Hygiene and Public Health, remaining in this position till his death. He gave courses and supervised research in that school.

In 1926 Pearl founded the "Quarterly Review of Biology", and in 1929 the journal "Human Biology." The former was an outlet for his interests in the wide and miscellaneous questions of biology. It included general articles reviewing the situation in particular fields, by authorities in those fields, lists of important new publications, and a department of comments

and reviews on recent literature,—a department that was much appreciated. The first year all of the reviews were written by Pearl himself. In later years much of the reviewing was taken over by others, though Pearl always edited the reviews. The journal "Human Biology" was devoted to the subject in which Pearl's chief interests lay; it published detailed investigations on the biology of man, a department of "notes", and extensive annotated lists of literature. After the founding of "Human Biology", Pearl was disposed to give up the Quarterly Review of Biology to other editorship, but whenever this question was raised so many objections were made that he kept on with it. Gradually Mrs. Pearl assumed a large share of the work of the Quarterly Review, enabling Pearl to direct his interest and energy mainly to "Human Biology", and to his researches and other publications.

Since Pearl's death the editorship of the Quarterly Review of Biology has been taken over by Professor B. H. Willier, Director of the Department of Biology of the Johns Hopkins University. Professor L. J. Reed has taken the editorship of Human Biology.

Pearl's interest was taken most strongly perhaps by two subjects in human biology. These were longevity and fertility. He may be said to have made hobbies of these. For many years he collected books and articles on longevity, spending much time on his trips to Europe and elsewhere in searching for publications in this field. He formed thus a great collection of works on longevity, probably one of the most complete in existence. This is now housed temporarily in the Welch Library at Johns Hopkins. Longevity formed one of the most frequent subjects of Pearl's writings.

On fertility Pearl collected a great bibliography with abstracts. He had worked on this for ten years before his death. This bibliography has been given to the Welch Library of the Johns Hopkins University. In the Department of Biostatistics of the Johns Hopkins University have been placed Pearl's departmental records, and many of his books and collections of data. Among the latter is a twenty volume collection of suicide records.

Longevity, fertility and population problems continued Pearl's chief lines of interest to the last, though he was interested in all activities of man, looking upon them as biological phenomena. His last book, published in 1939, was on "The Natural History of Population." In 1938 he gave a series of lectures at the University of Indiana with the title "Man; the Unique Mammal." These were to have been published as a book to be entitled "Man the Animal." This book may yet appear; the question of publishing it is as yet unsettled.

In the later years Pearl's family collaborated with him in scientific work. Mrs. Pearl took a large share in the editing of the journals. Their daughter Ruth D. Pearl collaborated with him in his studies of longevity, and was joint author with him of the book on the Ancestry of the Long-lived (1934).

As became a student of the biology of man, Pearl was interested in his own forbears, and this interest was a not unimportant influence in his life. He and Mrs. Pearl collected the town histories of the region in which his family had lived—northeastern Massachusetts, southwestern Maine and southern New Hampshire. These contain full records of the Pearl family. The first to settle in this country was John Pearl, who traced his ancestry to Pearls who entered England at the time of the Norman Conquest. He came to this country some time before 1670, and settled ultimately at Boxford, not far from Salem, on a 200 acre farm that has belonged to the Pearl family or some of its branches ever since. The house in which John Pearl lived was a barracks house, built for defense against the Indians. It was bought in 1926 by the Boston Museum of Fine Arts, and two of its rooms are now on display in the Museum as the best extant example of the builder's art of early colonial times. The house has long been known as the "Pearl-Webster" house, a daughter of the original John Pearl having married a Webster, their descendants continuing to live in the house. Raymond Pearl descended from a second John, son of the original John Pearl. This second John moved north from Boxford and settled in what is now the region of New Hampshire known as Farmington. All of Raymond Pearl's ancestors go back to the original settlers of that general region; he was the first of

his line to leave Farmington and marry an outsider. "Throughout his life he felt himself a north of Boston man and cultivated and cherished the sentiments and some of the prejudices of his people", remarks his friend L. J. Henderson.[2]

The subjects of Pearl's works are precisely those aspects of biology that are of the most general interest. This fact, with his intense interest in the propagation of scientific knowledge, kept him in demand as a public lecturer. He was a special lecturer at the State College of Iowa at Ames, in 1910, at the Michigan Agricultural College at Lansing in 1912, and at University College, London, in 1927. He gave the Lowell Lectures at Boston in 1920, the Harrington Lectures at the University of Buffalo in 1928, the Heath Clark Lectures at University College, London, in 1937, the Patten Lectures at the University of Indiana in 1938. In the meantime he gave many single lectures and addresses in many parts of the United States, including one of the commemoration addresses at the University of Michigan Centenary in 1937.

Pearl's activities in many diverse fields brought him many honors and responsibilities. The University of Maine conferred on him the degree of LL.D.; Dartmouth College the honorary degree of Sc.D.; St. John's College, Annapolis, that of Litt.D. He was decorated as Knight (later Officer) of the Crown of Italy. He was elected in 1940 Honorary Member of the Royal Society of Medicine, in the Section of Epidemiology and State Medicine.

He was elected a member of the National Academy of Sciences in 1916 and was a member of its Council from 1919 to 1925. He was also a member of the American Philosophical Society and of the American Academy of Arts and Sciences. He was a member of the National Research Council, Member of its Executive Council, and Chairman of its Agricultural Committee in 1916-1918. He was a member of the Board of Visitors and Governors of St. John's College, Annapolis, 1928 to 1934; Trustee of Science Service 1929 to 1935.

[2] Yearbook for 1940 of the American Philosophical Society, page 431.

He was Associate Editor of *Biometrika* from 1906 to 1910, of the *Journal of Agricultural Research,* 1914 to 1918. At the time of his death, beside his own journals, he was a member of the editorial boards of *Genetics*, the *Journal of Experimental Zoology*, *Metron*, *Biologia Generalis,* and *Acta Biotheoretica.*

He was President of the American Society of Zoologists in 1913, of the American Society of Naturalists (1916-17); President of the American Statistical Association (1939), of the American Association of Physical Anthropologists (1934 to 1936) and of the International Union for Scientific Investigation of Population Problems, 1928 to 1930.

Pearl was active in many directions outside the vast scientific and professional activities above outlined. He was socially prominent and popular, of wide acquaintance in America and England, and numbered among his friends some of the most interesting personalities of his time. At the clubs to which he belonged in Baltimore he gave excellent dinners. "There was his delight in being a connoisseur of good food and wines, and his almost boyish delight in playing at times the role par excellence himself of amateur cook and salad mixer", says the characterization in "Dartmouth '99." We have seen that he was an amateur musician of unusual ability and drive. At times he nursed along an evening amateur musical ensemble, composed of members of his family and of neighboring families or of scientific associates. For a short time the present writer took part in one of these, clarinet in hand, till he discovered that he had not a rhythmic soul. Pearl belonged in Baltimore to a group of choice spirits centering about H. L. Mencken, which, under the name of the Saturday Night Club, met for social and musical purposes. To the members of this club he dedicated his volume on "Alcohol and Longevity", with its cheering message. Helpful in grasping Pearl's points of view on the world and life is a small volume which he published in 1927, under the title "To Begin With, Being Prophylaxis Against Pedantry." This takes the form of advice as to the background of reading appropriate to the student of science as a man of the world. The point of view is sophisticated and somewhat cynical; the book is appropriately dedicated to H. L. Mencken.

During the summer of 1940 Pearl was very tired. A medical examination revealed only a low blood pressure. The physician ordered rest and week-end trips to get out of touch with work. The second of these week-end trips was the one to Hershey, November 16. The afternoon was spent in the zoological park; Pearl was tired but enthusiastic. He died that night, toward morning. The autopsy showed coronary thrombosis and a condition in the coronary artery that was bound to lead to prolonged illness or to sudden death.

## BIBLIOGRAPHY OF RAYMOND PEARL

1900-1941

(This bibliography was begun by Dr. Pearl himself and was completed by members of his department before the latter came to a close in June 1941.)

In this bibliography all titles cited are by Raymond Pearl alone, except where otherwise indicated by detailed citation of joint authorship.

Titles of *books* appear in their proper chronological order, but are distinguished from papers in journals etc. by prefixing the word [BOOK] before the citation of the title.

*1900*

On preparing earthworms for sectioning. *Journal of Applied Microscopy*, v. 3, p. 680.

Studies on electrotaxis. I.—On the reactions of certain infusoria to the electric current. *American Journal of Physiology*, v. 4, pp. 96-123.

A variation in the genital organs of *Lumbricus agricola* Hoffm. *Anatomischer Anzeiger*, Bd. 18, pp. 123-127.

Recent work in electrotaxis. *American Naturalist*, v. 34, pp. 977-979.

Reactions of the embryos and larvae of *Limulus*. [In "Zoological Journal Club of the University of Michigan"]. *Science*, N.S., v. 12, pp. 927-928.

Motor reactions of the ctenophore *Mnemiopsis leidyi*. [In "Zoological Journal Club" etc.]. *Ibid.*, p. 928.

*1901*

General physiology. *Journal of Applied Microscopy*, v. 4, pp. 1138-41; 1182-5; 1218-22; 1264-6; 1307-9; 1343-7; 1389-91; 1423-7; 1470-2; 1510-2; 1546-8; 1584-7.

Studies on the effects of electricity on organisms. II.—The reactions of *Hydra* to the constant current. *American Journal of Physiology*, v. 5, pp. 301-320.

Electrotaxis of infusoria. [In "Zoological Journal Club of the University of Michigan"]. *Science*, N.S., v. 13, pp. 745-746.

Some aspects of the electrotactic reaction of lower organisms. *Third Report Michigan Academy of Science*, pp. 73-74.

A curious habit of the slug *Agriolimax*. *Ibid.*, pp. 75-76.

The effect of very intense light on organisms. *Ibid.*, pp. 77-78. By R. P. and Leon J. Cole.

Certain reactions of the common slug *Agriolimax campestris* Binney. *Ibid.*, p. 79. By R. P. and Maud Mary DeWitt.

*1902*

Notes on technique, I. The preparation of sections of Hydra for class work. *Journal of Applied Microscopy and Laboratory Methods*, v. 5, pp. 1613-1614. By R. P. and Lewis H. Weld.

Notes on technique, II. The demonstration of nerve fibers in the ventral cord of the earthworm. *Ibid*, pp. 1614-1615

General physiology. *Ibid.*, pp. 1629-30; 1668-70; 1710-12; 1767-8; 1821-3; 1863-4; 1904-5; 1942-3; 2022-3; 2063-4; 2101-2.

Notes on technique, III. On injecting the blood vessels of the earthworm. *Ibid.*, pp. 1736-7.

*1903*

The movements and reactions of fresh-water planarians: A study in animal behaviour. *Quarterly Journal of Microscopical Science (London)*, v. 46, pp. 509-714.

General physiology. *Journal of Applied Microscopy and Laboratory Methods*, v 6, pp. 2151-2; 2197-8; 2247-9; 2292-3; 2344-6; 2392; 2434-5; 2481-4; 2536-8; 2582-3; 2632-3; 2711-4.

Planarians. *Ibid.*, pp. 2360-2. [Reprinted, without essential change, in 1904 in *A Booklet for Teachers of Zoology and Botany in the High Schools of Michigan*, pp. 19-21, published by the Michigan Academy of Science, Section of Science Teaching.]

Variation and correlation in *Arcella*. *Biometrika*, v. 2, pp. 321-337. By R P. and Frances J. Dunbar.

General laboratory technique. *Journal of Applied Microscopy and Laboratory Methods*, v. 6, pp. 2439-40; 2487-9; 2540; 2587-8; 2636; 2721-27.

Worcester's formol-sublimate fixing fluids. *Ibid.*, p. 2451.

On the mortality due to congenital malformations, with special reference to the problem of the relative variability of the sexes. *Medicine* (Detroit). November No., pp. (of reprint) 1-15.

On two cases of muscular abnormality in the cat. *Biological Bulletin*, v. 5, pp. 336-341.

True hermaphroditism in man. *American Medicine*, v. 6, p. 802.

*1904*

On the behavior and reactions of *Limulus* in early stages of its development. *Journal of Comparative Neurology and Psychology*, v. 14, pp. 138-164.

Variation and correlation in the earthworm. *Fifth Annual Report Michigan Academy of Science*, pp. 200-202. By R. P. and Wilbur N. Fuller.

Variation and correlation in *Arcella*. *Ibid.*, pp. 202-204. By R. P. and Frances J. Dunbar.

A statistical study of conjugation in *Paramecium*. *Sixth Annual Report Michigan Academy of Science*, pp. 184-185. By R. P. and Mary J. Burr.

Relative variability of man and woman [In "*Research Club of the University of Michigan*."] *Science*, N. S., v. 19, p. 73.

The Michigan Academy of Science. *Ibid.*, pp. 787-790. [Report of R. P. as Secretary of the Academy.]

*1905*

A notable advance in the theory of correlation *Science*, N. S., v. 21, pp 32-35.
Note on variation in the ray flowers of *Rudbeckia*. *American Naturalist*, v. 39, pp. 87-8.
Biometrical studies on man. I. Variation and correlation in brain-weight. *Biometrika*, v. 4, pp. 13-104.
Variation and correlation in the earthworm. *Ibid.*, pp. 213-229. By R. P. and Wilbur N. Fuller.
Some results of a study of variation and correlation in brain-weight. *Journal of Comparative Neurology and Psychology*, v. 15, pp. 467-481.
Some results of a study of variation in *Paramecium*. *Seventh Report Michigan Academy of Science*, pp. 77-86. By R. P. and Frances J. Dunbar.
A note on the calculation of certain probable errors. *Science*, N. S., v. 22, pp. 802-803.

*1906*

C. L. Redfield's theory of heredity. *The Horseman and Spirit of the Times*, Jan. 30, 1906.
On the mean duration of life of individuals dying within a year after birth. *Biometrika*, v. 4, pp. 510-16.
A biometrical study of conjugation in *Paramecium*. *Proceedings of the Royal Society, B*, (London), v. 77, pp. 377-383.
On the correlation between intelligence and the size of the head. *Journal of Comparative Neurology and Psychology*, v. 16, pp. 189-199.
Variation in the number of seeds of the lotus. *American Naturalist*, v. 40, pp. 757-768.
The calculation of the probable errors of certain constants of the normal curve. *Biometrika*, v. 5, p. 190.
Variation in *Chilomonas* under favourable and unfavourable conditions. *Ibid.*, pp. 53-72.
Bibliography. *Ibid.*, pp. 210-212. [An annotated bibliography of current biometric literature.]
Allgemeine Biologie und Entwickelungslehre. *Zoologischer Jahresbericht für 1905*, pp. 1-20. By Paul Mayer and R. P.

*1907*

Review of *The Behavior of Lower Organisms* by H. S. Jennings. *Journal of Comparative Neurology and Psychology*, v. 17, pp. 91-97.
A biometrical study of conjugation in *Paramecium*. *Biometrika*, v. 5, pp. 213-297.
[BOOK]. Variation and Differentiation in *Ceratophyllum*. *Washington, D. C.* (Carnegie Institution, Publication No. 58). Pp. 1-136. ["With the Assistance of Olive M. Pepper and Florence J. Hagle."]
Morphogenetic localization in *Aglaophenia*. *Science*, N. S., v. 25, p. 781.

The physical characteristics of the insane. *The Independent*, July 18, 1907, pp. 157-158.

Bibliography. *Biometrika*, v. 5, pp 482-486.

[BOOK]. Variation and Correlation in the Crayfish with Special Reference to the Influence of Differentiation and Homology of Parts. *Washington, D. C.* (Carnegie Institution, Publication No. 64). Pp. 1-70. By R. P. and A. B. Clawson.

Evolution and the origin of life. *The Dial*, October 1, 1907, pp. 208-211.

Allgemeine Biologie und Entwickelungslehre. *Zoologischer Jahresbericht für 1906*, pp. 1-23. By Paul Mayer and R. P.

Eugenics. *New York Evening Post*. *Ca.* October 8, 1907.

A case of triplet calves with peculiar color inheritance. *Science*, N. S., v. 26, p. 760.

*1908*

Breeding better men. The new science of eugenics which would elevate the race by producing higher types. *The World's Work*, January No., pp. 9818-9824

Some results of a biometrical study of egg production in the domestic fowl. *Science*, N. S, v. 27, pp. 449-450. By R. P. and Frank M. Surface.

On certain points concerning the probable error of the standard deviation. *Biometrika*, v. 6, pp. 112-117.

Bibliography. *Ibid.*, pp. 124-128; 445-451.

An abnormality of the venous system of the cat, with some considerations regarding adaptation in teratological development. *Archiv für Entwicklungsmechanik*, Bd. 25, pp. 648-654.

Biometrics. Recent contributions to theory. *American Naturalist*, v. 42, pp. 418-422.

Eugenics. Book List No. 24. *The Independent*.

Resection and end-to-end anastomosis of the oviduct in the hen, without loss of function. *American Journal of Physiology*, v. 22, pp. 357-361. By R. P. and Frank M. Surface.

Review of *Mental and Moral Heredity in Royalty*, by F. A. Woods. *Biometrika*, v. 6, p. 445.

Heredity. *The Independent*, August 13, pp. 376-377.

Appliances and methods for pedigree poultry breeding. *Maine Agricultural Experiment Station Bulletin 159*, pp. 239-274. By R. P. and Frank M. Surface.

On the relation of race crossing to the sex ratio. *Biological Bulletin*, v. 15, pp. 194-205. By R. P. and Maud DeWitt Pearl.

The organization and work of the Department of Biology of the Maine Agricultural Experiment Station. *Maine Agricultural Experiment Station Circular No. 330*, pp. 1-8.

Review of *Biology and its Makers*, by W. A. Locy. *The Independent*, October 1.

Review of *The Problem of Age, Growth and Death*, by Charles Sedgwick Minot. *Ibid.*, October.

Great movements and leaders in biologic science. *The Dial.*

*1909*

The use of atropin sulphate in anaesthetizing birds for surgical experiments. *Journal of the American Medical Association*, v. 52, pp. 382-3. By R. P. and Frank M. Surface.

Regulation in the morphogenetic activity of the oviduct of the hen. *Science*, N. S., v. 29, p. 428.

The nature of the stimulus which causes a shell to be formed on a bird's egg. *Ibid.*, p. 429. By R. P. and F. M. Surface.

A note on the degree of accuracy of biometric constants. *American Naturalist*, v. 43, pp. 238-240.

Evolution upside down. *The Dial*, v. 46, p. 24.

Poultry notes—1908. *Maine Agricultural Experiment Station Bulletin 165*, pp. 29-48. By R. P. and F. M. Surface.

Review of *The Physical Basis of Civilization*, by T. W. Heineman. *The Independent*, p. 1070.

Studies on the physiology of reproduction in the domestic fowl. II. Data on the inheritance of fecundity obtained from the records of egg production of the daughters of "200-egg" hens. *Maine Agricultural Experiment Station Bulletin 166*, pp. 49-84. By R. P. and F. M. Surface. [Abstract for popular distribution published as *Maine Agricultural Experiment Station Circular 345*, pp. 1-4.]

Data on variation in the comb of the domestic fowl. *Biometrika*, v. 6, pp. 420-432. By R. P. and Maud DeWitt Pearl.

The frequency constants of a variable $z = f(x_1, x_2)$. *Ibid.*, pp. 437-438.

Biometrics. Some recent studies on growth. *American Naturalist*, v. 43, pp. 302-316.

Apparate und Methoden, die bei experimentellen Unterschungen über Vererbung beim Geflügel gebraucht werden. *Zeitschrift für biologische Technik und Methodik*, Bd. 1, pp. 285-299. By R. P. and F. M. Surface.

A notable contribution to biology. *The Dial*, v. 46, p. 267.

Studies on the physiology of reproduction in the domestic fowl. I. Regulation in the morphogenetic activity of the oviduct. *Journal of Experimental Zoology*, v. 6, pp. 339-359, 2 plates. [*Autoreferat* of this paper in *Archiv für Entwicklungsmechanik*, Bd. 28, Heft 1.]

Methods of poultry management at the Maine Agricultural Experiment Station. *U. S. Department of Agriculture Farmers' Bulletin 357*, pp. 1-39.

A biometrical study of egg production in the domestic fowl. I. Variation in annual egg production. *U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 110*, Part I, pp. 1-80. By R. P. and F. M. Surface.

[Folklore of hen's eggs.] *Boston Evening Transcript*, May 29.

Selection index numbers and their use in breeding. *American Naturalist*, v 43, pp. 385-400. By R. P. and F. M. Surface

Transformations in the world of animal life. *The Dial*, v 47, p. 76.

Review of *Anwendung elementarer Mathematik auf biologische Probleme*, by Przibram. *Science*, N. S., v. 30, pp. 153-155.

Review of *Essays Biographical and Chemical*, by Sir William Ramsay. *The Independent*, v. 67, p. 367.

Taking stock of Darwinism. *The Dial*, v. 47, pp. 92-94.

Review of *Fifty Years of Darwinism*. *The Independent*, v. 67, p. 480.

Review of *Mendel's Principles of Heredity*, by William Bateson. *Ibid.*, p. 762.

Studies on the physiology of reproduction in the domestic fowl. III. A case of incomplete hermaphroditism. *Biological Bulletin*, v. 17, pp. 271-287. By R. P. and Maynie R. Curtis.

Studies on the physiology of reproduction in the domestic fowl. IV. Data on certain factors influencing the fertility and hatching of eggs. *Maine Agricultural Experiment Station Bulletin 168*, pp. 105-164. By R. P. and F. M. Surface. [Condensed edition issued to farmers as *Maine Agricultural Experiment Circular 363*, pp. 1-6.]

Foundations of Darwin's famous book. *The Dial*, v. 47, p. 380.

Is there a cumulative effect of selection? *Zeitschrift für induktive Abstammungs- und Vererbungslehre*, Bd. 2, pp. 257-275. By R. P. and F. M. Surface.

How to keep poultry free from lice. *Maine Agricultural Experiment Station Circular 352*, pp. 1-3.

The poultry work of the Maine Agricultural Experiment Station. *Ibid.*, *369*, pp. 1-6.

*1910*

Some evolution house-cleaning. *The Dial*, v. 48, pp. 12-13.

Bibliography. *Biometrika*, v. 7, pp. 414-420.

Intra-individual variation and heredity. *Proceedings of the Seventh International Zoological Congress*, pp. (of reprint), 1-3.

On the wrong tracks of life. *The Dial*, v. 48, pp. 116 117.

For the culture of the race. *Ibid.*, p. 125.

Race culture. *The Independent*, February 24, pp. 418-419.

A triple-yolked egg. *Zoologischer Anzeiger*, Bd. 35, pp. 417-423.

How can we breed 200-egg hens? *Farm and Home*, v. 31, p. 85.

A classic of biological literature. *The Dial*, v. 48, pp. 316-317.

The relation of the results obtained in breeding poultry for egg production to problem of selection. *Society for the Promotion of Agricultural Science, 30th Meeting*, pp. (of reprint) 1-8.

Biology and medicine. *The Dial*, v. 48, pp. 360-361.

Recent quantitative studies on variation in social insects. *American Naturalist*, v. 44, pp. 308-316.

The possible eugenic bearing of certain experiments with poultry. *Eugenics Review* (London), v. 2, pp. 25-29.

On the inheritance of the barred color pattern in poultry. *Archiv für Entwicklungsmechanik*, Bd. 30, pp. 45-61, 2 plates. By R. P. and F. M. Surface.

Breeding for production in dairy cattle in the light of recent advances in the study of inheritance. *Eighth Annual Report of the Commissioner of Agriculture of Maine*, pp. 118-129.

Poultry notes—1909. *Maine Agricultural Experiment Station Bulletin 179*, pp. 65-124. By R. P. and F. M. Surface. [Condensed edition issued to farmers as *Maine Agricultural Experiment Station Circular 391*, pp. 1-20.]

Studies on hybrid poultry. *Maine Agricultural Experiment Station Annual Report, 1910*, pp. 84-115. By R. P. and F. M. Surface.

Inheritance of hatching quality of eggs in poultry. *American Breeder's Magazine*, v. 1, pp. 129-133.

Experiments in breeding sweet corn. *Maine Agricultural Experiment Station, Annual Report 1910*, pp. 249-307. By R. P. and F. M. Surface.

Practical suggestions regarding the growing of sweet corn for packing and for seed. *Maine Agricultural Experiment Station Circular 393*, pp. 1-8. By R. P. and F. M. Surface.

The pragmatic standpoint in philosophy. *The Dial*, v. 49, pp. 183-184.

Evolution and the Irish. *Ibid.*, p. 290.

Mutation. *The Independent*, November 24, pp. 1157-1158

Further data regarding the sex-limited inheritance of the barred color pattern in poultry. *Science*, N. S., v. 32, pp. 870-874. By R. P. and F. M. Surface.

*1911*

Data on the relative conspicuousness of barred and self-colored fowls. *American Naturalist*, v. 45, pp. 107-117.

Review of *Atavism in guinea-chicken hybrids*, by M. F. Guyer. *Zeitschrift für Abstammungs- und Vererbungslehre*, 1911, pp. 298-299.

Review of *The First Principles of Heredity*, by A. S. Herbert. *The Dial*, v. 50, p. 60.

Vegetarian biology. *Ibid.*, p. 128.

A note regarding variation in the single combs of fowls. *Mendel Journal*, v. 1, pp. 180-195. [Also published as *Maine Agricultural Experiment Station Circular 412*, pp. 1-7.]

A biometrical study of egg production in the domestic fowl. II. Seasonal distribution of egg production. *U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 110*, Part II, pp. 81-170. By R. P. and F. M. Surface.

Davenport's "Inheritance of Characteristics in Domestic Fowl." *Science*, N. S., v. 33, pp. 328-330.

Poultry diseases and their treatment. *Maine Agricultural Experiment Station Circular 398*, pp. ix + 216. By R. P., F. M. Surface, and Mayme R. Curtis.

Biometrics. An introduction to statistical methods. *American Naturalist*, v. 45, pp. 319-320.

Inheritance of fecundity in the domestic fowl. *Ibid.*, pp. 321-345.

Inheritance in "blood lines" in breeding animals for performance, with special reference to the "200-egg hen." *Annual Report American Breeders Association*, v. 6, pp. 317-326.

Some recent studies on variation and correlation in agricultural plants. *American Naturalist*, v. 45, pp. 415-425.

Opportunities for corn breeding in Maine. *Maine Seed Improvement Association Annual Report for 1910*, pp. 146-155.

Biometric arguments regarding the genotype concept. *American Naturalist* v. 45, pp. 561-566.

An eighteenth-century patron of science. *The Dial*, v. 51, pp. 255-256.

Biometric ideas and methods in biology. Their significance and limitations. *Scientia*, v. 10, pp. 101-119. [French translation, "Les idées et méthodes biométriques en biologie. Leur signification et leurs limitations." *Ibid.*, pp. 62-81.]

Evolution: as speculation and as fact. *The Dial*, v. 51, pp. 207-208.

The personal equation in breeding experiments involving certain characters of maize. *Biological Bulletin*, v. 21, pp. 339-366.

The Mendelian inheritance of certain chemical characters in maize. *Zeitschrift für induktive Abstammungs- und Vererbungslehre*, Bd. 6, pp. 1-28. By R. P. and James M. Bartlett.

The "Seasons" of a later Thomson. *The Dial*, v. 51, pp. 531-532.

A note on certain biometrical computations. *American Naturalist*, v. 45, pp. 756-760. By R. P. and Lottie E. McPheters.

Breeding poultry for egg production. *Maine Agricultural Experiment Station Annual Report for 1911*, pp. 113-176.

On the accuracy of trap nest records. *Ibid.*, pp. 186-193.

Poultry notes—1910. *Maine Agricultural Experiment Station Bulletin 193*, pp. 177-200.

*1912*

Studies on the physiology of reproduction in the domestic fowl. V. Data regarding the physiology of the oviduct. *Journal of Experimental Zoology*, v. 12, pp. 99-132. By R. P. and Maynie R. Curtis.

Killing temperatures for hens' eggs. *Breeder's Gazette*, v. 61, p. 257.

Making life in a test tube. *The Dial*, v. 52, pp. 84-85.

Methods of feeding poultry. *Maine Agricultural Experiment Station Circular 447*, pp. 1-4.

A case of hypospadias in a ram. *American Veterinary Review*, March, pp. 2-4.

Review of *History of Biology*, by L. C. Miall. *The Dial*, v. 52, p. 28.

The work of the Maine Agricultural Experiment Station in breeding poultry for egg production. *Practical Husbandry of Maine*, v. 2, pp 136-139.

Genetics and eugenics a consideration of the relation of animal experimentation to human inheritance and infant conservation. *Eugenics Review* (London), v. 3, pp. 335-339. [Also reprinted in *Proceedings of the American Association for the Study and Prevention of Infant Mortality for 1911*, pp. 129-132.]

Functions of the comb and wattles. *American Poultry World*, v 3, p. 451. [Also reprinted in *Poultry* (London), June 21, 1912, p. 979 ]

Notes on the history of barred breeds of poultry. *Biological Bulletin*, v. 22, pp. 297-308.

Further notes regarding selection index numbers. *American Naturalist*, v. 46, pp. 302-307

Recent discussions of heredity. *The Dial*, v. 52, pp 397-398.

The inheritance of fecundity. *Popular Science Monthly*, October, pp. 364-373. [Also repinted in *Problems in Eugenics. Papers communicated to the First International Eugenics Congress, London*, pp. 47-57.]

Breeding poultry. *Proceedings of the New York Farmers. Season 1911-12*, pp. 37-53.

Controlling man's evolution. *The Dial*, v. 53, pp. 49-51.

The secretory activity of the oviduct of the domestic fowl. *Proceedings Society for the Promotion of Agricultural Science for 1911*, pp. 29-34.

The mode of inheritance of fecundity in the domestic fowl. *Journal of Experimental Zoology*, v. 13, pp. 153-268. [Also reprinted, with some alterations, in *Maine Agricultural Experiment Station, Annual Report for 1912*, pp. 283-304.]

The First International Eugenics Congress. *The Independent*, Sept. 12, pp. 614-616.

The First International Eugenics Congress. *Science*, N.S., v. 36, pp. 395-396.

Problems of evolution. *The Dial*, v. 53, pp. 136-137.

How many eggs can a hen lay? *Farm and Fireside*, November 9, p. 12.

A case of triplet calves, with some general considerations regarding multiple gestation in normally uniparous animals. *Maine Agricultural Experiment Station Annual Report for 1912*, pp. 259-282.

Mathematico-procrustean art. *The Dial*, v. 53, p. 380.

Is there an "egg type" in the domestic fowl? *Farm and Fireside*, v. 36, No. 5, December 7, 2 pp.

The Mendelian inheritance of fecundity in the domestic fowl. *American Naturalist*, v. 46, pp. 697-711.

Breeding for egg production. *Farm and Fireside*, v. 36, December 21, 2 pp.

Fat deposition in the testis of the domestic fowl. *Science*, N. S.,v. 36, pp. 833-835. By R. P. and Alice M. Boring.

*1913*

The living machine. *The Dial,* v. 54, pp. 51-52

The story of evolution. *Ibid.,* pp. 61-62.

Note regarding the relation of age to fecundity. *Science,* N. S., v. 37, pp. 226-228.

The fear of inbreeding. *Farm and Home,* Feb. 1, pp. 76 and 86 [Also reprinted in *Feathered Life* (London), March 12, p. 168.]

An experimental investigation of the laws of milk production. A need and an opportunity. *Practical Husbandry of Maine,* v. 3, pp. 241-244.

Vincent Astor's aim. To found a Rockefeller Institute of farming research, *New York Times,* February 21.

Animal evolution by mutation. *The Dial,* v. 54, pp. 249-250.

Review of *The Right of the Child to be Well Born,* by G. E. Dawson. *The Dial,* v. 54, p. 251.

Data on sex determination in cattle. *Biological Bulletin,* v. 24, pp. 205-225. By R. P. and Howard M. Parshley.

The contribution of poultry husbandry to the science of genetics. *Illustrated Poultry Record* (London), April No., pp. 300-1.

Genetics and breeding. *Science,* N. S., v. 37, pp. 539-546.

Methods of Poultry Management at the Maine Agricultural Experiment Station (Revised to February, 1913). *Maine Agricultural Experiment Station Circular 471,* pp. 1-78.

The need for endowed agricultural research. *Science,* N. S., v. 37, pp. 707-709.

Note on the sex behavior of the Poitou jacks. *Journal of Animal Behavior,* v. 3, pp. 297-209.

Natural theology without theistic implications. *The Dial,* v. 55, pp. 111-112.

The biology of poultry keeping. *Maine Agricultural Experiment Station Annual Report for 1913,* pp 101-120.

The measurement of the intensity of inbreeding. *Maine Agricultural Experiment Station Bulletin 215,* pp. 123-138.

A contribution towards an analysis of the problem of inbreeding. *American Naturalist,* v. 47, pp. 577-614.

Breeding for heavy egg production. *Reliable Poultry Journal,* v. 20, pp. 812-813; 860-862.

Poultry notes 1911-1913. *Maine Agricultural Experiment Station Bulletin 216,* pp. 141-168.

Reconciling religion and Darwinism. *The Dial,* v. 55, p. 362.

Cabbages and the cosmos. *Ibid.,* p. 412.

An introduction to the study of evolution. *Ibid.,* pp. 414-415.

Tables for calculating coefficients of inbreeding. *Maine Agricultural Experiment Station Annual Report for 1913,* pp. 191-202. By R. P. and John R. Miner.

On the correlation between the number of mammæ of the dam and size of litter in mammals. I. Interracial correlation. *Proceedings of the Society for Experimental Biology and Medicine*, v. 11, pp. 27-30.

On the correlation between the number of mammæ of the dam and size of litter in mammals. II. Intraracial correlation in swine. *Ibid.*, pp. 31-32.

Breeding for egg production. *Poultry Institute . . . 38th Annual Meeting of the American Poultry Association*, pp. 10-14.

Breeding poultry for egg production. *The Farmer's Advocate*, December 11, 1913, pp. 2160-2161.

Recent discoveries which may modify breeding practice. *Breeder's Gazette*, v. 64, pp. 1206, 1273, 1279-1280.

Biology. *Maine Agricultural Experiment Station Circular 485*, pp. 19-33.

Die Furcht vor der Inzucht. *Gefluegelzuechter für das Jahr 1914*, pp. 43-45. [Actually published in 1913.]

Constants for normal variation in the fat content of mixed milk. *Maine Agricultural Experiment Station Annual Report for 1913*, pp. 299-305.

Variation in the tongue color of Jersey cattle. *Proceedings of the Society for the Promotion of Agricultural Science 1913*, pp. (of reprint) 1-9.

The relative time of fertilization of the ovum and the sex ratio amongst Jews. *American Anthropologist*, N. S., v. 15, pp. 668-674. By R. P. and Redcliffe N. Salaman.

*1914*

On the results of inbreeding a Mendelian population: a correction and extension of previous conclusions. *American Naturalist*, v. 48, pp. 57-62.

The odd chromosome in the spermatogenesis of the domestic chicken. *Journal of Experimental Zoology*, v. 16, pp. 53-83. By Alice M. Boring and R. P.

The biology of sex. *The Dial*, v. 56, pp. 145-146.

Some physiological observations regarding plumage patterns. *Science*, N. S., v. 39, pp. 143-144. By R. P. and Alice M. Boring.

Possibilities in breeding for milk production. *Hoard's Dairyman*, v. 47, pp. 41, 54-55.

A table for estimating the probable significance of statistical constants. *Maine Agricultural Experiment Station Annual Report for 1914*, pp. 85-88. By R. P. and John R. Miner.

The service and importance of statistics to biology. *Quarterly Publications of the American Statistical Association*, March, pp. 40-48.

Review of *Artificial Parthenogenesis and Reproduction* by Jacques Loeb. *The Dial*, v. 56, p. 391.

Biological problems of today. *Ibid.*, p. 469.

Looking glass music. *The Independent*, June 8, 1 p.

A biometrical study of egg production in the domestic fowl. III. Variation and correlation in the physical character of the egg. *U. S. Department of Agriculture Bureau of Animal Industry, Bulletin 110, Part III*, pp. 171-241. By R. P. and F. M. Surface.

Studies on inbreeding.—IV. On a general formula for the constitution of the *n*th generation of a Mendelian population in which all matings are of brother x sister. *American Naturalist*, v. 48, pp 491-494.

Biometrics. An important contribution to theory. *Ibid.*, pp 505-507

Studies on the physiology of reproduction in the domestic fowl VII. Data regarding the brooding instinct in its relation to egg production. *Journal of Animal Behavior*, v. 4, pp. 266-288.

A Jersey landmark gone. *Hoard's Dairyman*, v. 48, p. 144.

The measurement of changes in the rate of fecundity of the individual fowl. *Science*, N. S., v. 40, pp. 383-384.

Studies on inbreeding. V. Inbreeding and relationship coefficients. *American Naturalist*, v. 48, pp. 513-523.

Improving egg production by breeding. *Maine Agricultural Experiment Station Annual Report for 1914*, pp. 217-236.

Studies on the physiology of reproduction in the domestic fowl. VIII. On some physiological effects of the ligation, section, or removal of the oviduct. *Journal of Experimental Zoology*, v. 17, pp. 395-424. By R. P. and Maynie R. Curtis.

Studies on the physiology of reproduction in the domestic fowl. IX. On the effect of corpus luteum substance upon ovulation in the fowl. *Journal of Biological Chemistry*, v. 10, pp. 263-278. By R. P. and F. M. Surface.

The policy of the journal. *Journal of the American Association of Instructors and Investigators in Poultry Husbandry*, v. 1, pp. 1-2. [An introductory editorial statement.]

Rural leadership. *Community Efficiency Conference, Augusta, Maine, November 1914*, pp. 18-20.

The color of the hen's legs. *Maine Agricultural Experiment Station Circular 499*, pp. 1-4.

On the law relating milk flow to age in dairy cattle. *Proceedings of the Society for Experimental Biology and Medicine*, v. 12, pp. 18-19.

On the refractive index of the serum in a guinea-chicken hybrid. *Ibid.*, p. 48. By R. P. and John W. Gowen.

Brief report of progress on animal husbandry investigations in 1914. *Maine Agricultural Experiment Station Circular 503*, pp. 1-11.

*1915*

Influence of the male bird in producing prolific layers. *Inland Poultry Journal*, v. 20, September No., 3 pp.

Introductory statement on the use of logarithmic curves in biological and agricultural investigations. *Journal of Agricultural Research*, v. 3, pp. 411-412.

Studies on outbreeding. II. Selection within pure lines. *Maine Agricultural Experiment Station Annual Report for 1915*, pp. 1-40. By F. M. Surface and R. P.
Results with oats which help towards the solution of some fundamental problems of plant and animal breeding. *Maine Agricultural Experiment Station Circular 504*, pp. 1-7. By R. P. and F. M. Surface.
Interpolation as a means of approximation to the gamma function for high value of *n*. *Science*, N. S., v. 41, pp. 506-507.
A case of assumption of male secondary sex characters by a cow. *Ibid.*, pp. 615-616. By R. P. and F. M. Surface.
Growth and variation in maize. *Proceedings of the National Academy of Sciences*, v. 1, pp. 222-226. By R. P. and F. M. Surface
Mendelian inheritance of fecundity in the domestic fowl, and average flock production. *American Naturalist*, v. 49, pp. 306-317.
Sex studies. VII. On the assumption of male secondary characters by a cow with cystic degeneration of the ovaries. *Maine Agricultural Experiment Station Annual Report for 1915*, pp. 65-80. By R. P. and F. M. Surface.
Cystic degeneration of the ovaries in a cow accompanied by the assumption of the external appearance of a bull. *Maine Agricultural Experiment Station Circular 508*, pp. 1-4. By R. P. and F. M. Surface.
Studies on the physiology of reproduction in the domestic fowl. XIII. On the failure of extract of pituitary body (anterior lobe) to activate the resting ovary. *Journal of Biological Chemistry*, v. 21, pp. 95-101. By R. P. and F. M. Surface.
Dynamic evolution. *Journal of Heredity*, v. 6, pp. 254-256.
Studies on the physiology of reproduction in the domestic fowl. X. Further data on somatic and genetic sterility. *Journal of Experimental Zoology*, v. 19, pp. 45-59. By M. R. Curtis and R. P.
Studies on bean breeding. I. Standard types of yellow-eye beans. *Maine Agricultural Experiment Station Annual Report for 1915*, pp. 161-176. By R. P. and F. M. Surface.
Suggestions for breeding yellow-eye beans of standard types. *Maine Agricultural Experiment Station Circular 510*, pp. 1-4. By R. P. and F. M. Surface.
Breeding for sex. *Hoard's Dairyman*, v. 50, p. 71.
Studies on inbreeding. VI. Some further considerations regarding cousin and related kinds of mating. *American Naturalist*, v. 49, pp. 570-575.
Growth and variation in maize. *Zeitschrift für induktive Abstammungs- und Vererbungslehre*, Bd. 14, pp. 97-203. By R. P. and F. M. Surface.
A system of recording types of mating in experimental breeding operations. *Science*, N. S., v. 42, pp. 383-386.
Seventeen years selection of a character showing sex-linked Mendelian inheritance. *American Naturalist*, v. 49, pp. 595-608.

[BOOK] Modes of Research in Genetics. *New York* (The Macmillan Co.). Pp. vii + 182.

[BOOK] Diseases of Poultry Their Etiology, Diagnosis, Treatment and Prevention. *New York* (The Macmillan Co.). Pp. xi + 342. By R. P., F. M Surface, and M. R. Curtis.

The publication of the results of investigations made in Experiment Stations in technical scientific journals. *Science,* N S, v. 42, pp. 518-522.

On the degree of exactness of the gamma function necessary in curve fitting. *Ibid.,* pp. 833-834.

Further data on the measurement of inbreeding. *Maine Agricultural Experiment Station Bulletin 243,* pp. 225-248.

Measurement of the winter cycle in the egg production of domestic fowl. *Journal of Agricultural Research,* v. 5, pp. 429-437.

Report of progress on animal husbandry investigations in 1915. *Maine Agricultural Experiment Station Circular 519,* pp. 1-27.

*1916*

Methods of poultry management at the Maine Agricultural Experiment Station. (Revised to January 1916). *Maine Agricultural Experiment Station Circular 515,* pp. 1-98.

On the effects of feeding pituitary body (anterior lobe) substance, and corpus luteum substance to growing chicks. *Proceedings of the National Academy of Sciences,* v. 2, pp 50-53.

The prince of "colyumists." *The Dial,* v. 60, pp. 157-160.

Fecundity in the domestic fowl and the selection problem. *American Naturalist,* v. 50, pp. 89-105.

Studies on the physiology of reproduction in the domestic fowl. XIV. The effect of feeding pituitary substance and corpus luteum substance on egg production and growth. *Journal of Biological Chemistry,* v. 24, pp. 123-135.

A method of correcting for soil heterogeneity in variety tests. *Journal of Agricultural Research,* v. 5, pp 1039-1050. By R. P. and F. M. Surface.

Report of the first Jersey sires futurity test of the Aroostook Jersey Breeders' Association. *Maine Agricultural Experiment Station Bulletin 247,* pp. 37-52.

On the effect of continued administration of certain poisons to the domestic fowl, with special reference to the progeny. *Proceedings of the American Philosophical Society,* v. 55, pp. 243-258.

The separate inheritance of plumage pattern and pigmentation in Plymouth Rocks. *Practical Husbandry of Maine,* April, 2 pp.

The animal-breeding industry. *Scientific Monthly,* v. 3, pp. 23-30.

The effect of parental alcoholism (and certain other drug intoxications) upon the progeny in the domestic fowl. *Proceedings of the National Academy of Sciences,* v. 2, pp. 380-384.

Studies on the physiology of reproduction in the domestic fowl. XV Dwarf eggs. *Journal of Agricultural Research*, v. 6, pp. 977-1042. 2 plates. By R. P. and M R. Curtis.

Data on the relation of the corpus luteum to primary and secondary sex characters. A summary of some recent experimental work. *Technical Supplement: Urological and Cutaneous Review*, v. 4, pp. (of reprint) 1-12.

Note on the proportions of the sexes in the whitefish. *Michigan Academy of Science 17th Report*, p. 76.

On the differential effect of certain calcium salts upon the rate of growth of the two sexes of the domestic fowl. *Science*, N. S., v. 44, pp. 687-688.

Dwarf eggs of the domestic fowl. *Maine Agricultural Experiment Station Annual Report for 1916*, pp. 289-328. By R. P. and M. R. Curtis.

Dwarf eggs. *Maine Agricultural Experiment Station Circular 530*, pp. 1-4. By R. P. and M. R. Curtis.

Some effects of the continued administration of alcohol to the domestic fowl, with special reference to the progeny. *Proceedings of the National Academy of Sciences*, v. 2, pp. 675-683.

On the degree of inbreeding which exists in American Jersey cattle. *Ibid.*, pp. 58-61. By R. P. and S. W. Patterson.

*1917*

The experimental modification of germ cells. I. General plan of experiments with ethyl alcohol and certain related substances. *Journal of Experimental Zoology*, v. 22, pp. 125-164.

The experimental modification of germ cells. II. The effect upon the domestic fowl of the daily inhalation of ethyl alcohol and certain related substances. *Ibid.*, pp. 165-186.

The experimental modification of germ cells. III. The effect of parental alcoholism, and certain other drug intoxications, upon the progeny. *Ibid.*, pp. 241-310.

The selection problem. *American Naturalist*, v. 51, pp. 65-91.

The probable error of a difference and the selection problem. *Genetics*, v. 2, pp. 78-81.

Some commonly neglected factors underlying the stock breeding industry. *Maine Agricultural Experiment Station Annual Report for 1917*, pp. 1-28.

The probable error of a Mendelian class frequency. *American Naturalist* v. 51, pp. 144-156.

Fertility and age in the domestic fowl. *Proceedings of the National Academy of Sciences*, v. 3, pp. 354-356.

Report of progress on animal husbandry investigations in 1916. *Maine Agricultural Experiment Station Annual Report for 1917*, pp. 121-144.

The change of milk flow with age, as determined from the seven day records of Jersey cows. *Ibid.*, pp. 145-152. By R. P. and S. W. Patterson.

The sex ratio in the domestic fowl. *Proceedings of the American Philosophical Society*, v. 56, pp. 416-436.

Studies on the physiology of reproduction in the domestic fowl. XVII The influence of age upon reproductive ability, with a description of a new reproductive index. *Genetics*, v. 2, pp. 417-432.

Studies on inbreeding. VII. Some further considerations regarding the measurement and numerical expression of degrees of kinship. *American Naturalist*, v. 51, pp. 545-559.

Studies on inbreeding. VIII. A single numerical measure of the total amount of inbreeding. *Ibid.*, pp. 636-639.

Sex studies. IX. Interstitial cells in the reproductive organs of the chicken. *Anatomical Record*, v. 13, pp. 253-268. By Alice M. Boring and R. P.

Factors influencing the sex ratio in the domestic fowl. *Science, N. S.*, v. 46, p. 220.

What can the Stations most profitably do to increase the efficiency of food production and conservation in the national emergency? *Proceedings of the 31st Annual Convention of the Association of American Agricultural Colleges and Experiment Stations*, pp. 256-260. [Dated 1917, but actually issued in 1918.]

*1918*

Sex studies. X. The corpus luteum in the ovary of the domestic fowl. *American Journal of Anatomy*, v. 23, pp. 1-16, 9 plates. By R. P. and Alice M. Boring.

Sex studies. XI. Hermaphrodite birds. *Journal of Experimental Zoology*, v. 25, pp. 1-47, 9 plates. By Alice M. Boring and R. P.

Excerpts of speech of Dr. Raymond Pearl, made in Washington, D. C., before a conference of home economics workers, February 1918. *Washington* (U. S. Food Administration), pp. 1-8.

War and prices. *Food News Notes for Libraries*, v. 1, No. 6, pp. 6-13.

A new price index. *Ibid.*, No. 7, pp. 4-8.

Biology and war. *Journal of the Washington Academy of Sciences*, v. 8, pp. 341-360.

When you eat in hotels this summer. *Ladies Home Journal*, July issue, 2 pp.

Wheat conservation the salvation of our allies. *The Annalist*, v. 12, p. 52. July 15 issue.

General index numbers of food prices on a nutritive value base. *Washington* (U. S. Food Administration), August. Pp. 1-13.

The seasonal distribution of swine breeding. *Scientific Monthly*, September issue. Pp. 244-251.

Exports of foodstuffs to the Western Allies. *Oregon Voter*, v. 14, pp. 237-239.

[BOOK] Reference Handbook of Food Statistics in Relation to the War. *Washington* (Government Printing Office). Pp. 1-124. By R. P. and Esther Pearl Matchett.

Some correspondence anent Food Administration figures. Mr. Pearl's reply. *The Annalist*, v. 12, pp. 366; 383. October 14 issue.

Statistics of garbage collection and garbage grease recovery in American cities. *Journal of Industrial and Engineering Chemistry*, v. 10, pp. 927-930.

Message to the poultry world. *Reliable Poultry Journal*, v. 25, p. 775.

*1919*

On the mean age at death of centenarians. *Proceedings of the National Academy of Sciences*, v. 5, pp. 83-86.

Sterilization of degenerates and criminals considered from the standpoint of genetics. Eugenics Review, v. 11, pp. 1-6.

The relative contribution of the staple commodities to the national food consumption. *Proceedings of the American Philosophical Society*, v. 58, pp. 182-222.

Influenza studies. I. On certain general statistical aspects of the 1918 epidemic in American cities. *Public Health Reports*, v. 34, pp. 1743-1783.

"Lion's" letters. *The Nation*, v. 108, pp. 837-838, May 24 issue.

A statistical discussion of the relative efficacy of different methods of treating pneumonia. *Archives of Internal Medicine*, v. 24, pp. 398-403.

Variation of Ayrshire cows in the quantity and fat content of their milk. *Journal of Agricultural Research*, v. 17, pp. 285-322 By R. P. and J. R. Miner. [A condensed version of this paper was also published in *Maine Agricultural Experiment Station Annual Report for 1919, Bulletin 279*, pp. 57-64.]

An appeal. *Science*, N. S., v. 50, pp. 524-525. [Also printed in *Quarterly Publications of the American Statistical Association*, v. 16, p. 546.]

Retail prices of food during 1917 and 1918. *Quarterly Publications of the American Statistical Association*, v. 16, pp. 411-439. By R. P. and Magdalen H. Burger.

Preliminary note on the incidence of epidemic influenza among the actively tuberculous. *Ibid.*, pp. 536-540.

Studies in milk secretion. VII. Transmitting qualities of Jersey sires for milk yield, butter-fat percentage and butter-fat. *Maine Agricultural Experiment Station Annual Report for 1919*, pp. 89-204. By R. P., John W. Gowen and John R. Miner.

On the embryological basis of human mortality. *Proceedings of the National Academy of Sciences*, v. 5, pp. 593-598.

*1920*

Food thrift. *Annals of the American Academy of Political and Social Science*, v. 87, pp. 118-127.

[BOOK] The Nation's Food. A Statistical Study of a Physiological and Social Problem. *Philadelphia* (W. B. Saunders Co.). Pp. 274.

Certain evolutionary aspects of human mortality rates. *American Naturalist*, v. 54, pp. 5-44.

The significance of some general biologic principles in public health problems. *Journal of the American Medical Association*, v. 74, pp. 375-378.

Review of *Inbreeding and Outbreeding, their Genetic and Sociological Significance*, by East and Jones. *Science*, N. S., v. 51, pp. 415-417.

A new statistical journal. *Ibid.*, pp. 515-517.

A contribution of genetics to the practical breeding of dairy cattle. *Proceedings of the National Academy of Sciences*, v. 6, pp. 225-233.

The effect of war on the chief factors of population change. *Science*, N. S., v. 51, pp. 553-556.

Some landmarks in the history of vital statistics. *Quarterly Publications of the American Statistical Association*, v. 17, pp. 221-223.

On the rate of growth of the population of the United States since 1790 and its mathematical representation. *Proceedings of the National Academy of Sciences*, v. 6, pp. 275-288. By R. P. and L. J. Reed.

On a single numerical index of the age distribution of a population. *Ibid.*, pp. 427-431.

The relative influence of the constitutional factor in the etiology of tuberculosis. *American Review of Tuberculosis*, v. 4, pp. 688-712.

Variation in the rate of infant mortality in the United States Birth Registration Area. *New York Medical Journal*, v. 112, pp. 1009-1014. [Also printed, with some changes, in *Eleventh Annual Meeting American Child Hygiene Association*, pp. 213-229, 1921.]

*1921*

A further note on war and population. *Science*, N. S., v. 53, pp. 120-126.

Influenza studies. II. Further data on the correlation of explosiveness of outbreak of the 1918 epidemic. *Public Health Reports*, v. 36, pp. 273-289.

Influenza studies. III. On the correlation of destructiveness of the 1918 epidemic. *Ibid.*, pp. 289-294.

Influenza studies. IV. On the correlation between explosiveness and total destructiveness of the epidemic mortality. *Ibid.*, pp. 294-298.

The biology of death. I. The problem. *Scientific Monthly*, v. 12, pp. 193-214.

The biology of death. II. Conditions of cellular immortality. *Ibid.*, 321-335.

The biology of death. III. The chances of death. *Ibid.*, pp. 444-456.

The biology of death. IV. The causes of death. *Ibid.*, pp. 489-516.

The biology of death. V. The inheritance of duration of life in man. *Ibid.*, v. 13, pp. 45-65.

The biology of death. VI. Experimental studies on the duration of life. *Ibid.*, pp. 143-162.
The biology of death. VII. Natural death, public health, and the population problem. *Ibid.*, pp. 193-212.
Forecasting the growth of nations. The future population of the world and its problems. *Harper's Magazine*, v. 142, pp. 704-713. May issue. By R. P. and Fred C. Kelly.
A biological classification of the causes of death. *Metron*, v. 1, No. 3, pp. 92-99.
Studies on the physiology of reproduction in the domestic fowl. XIX. On the influence of free choice of food materials on winter egg production and body weight. *American Journal of Hygiene*, v. 1, pp. 253-277. By R. P. and T. E. Fairchild.
The significance of biometry and vital statistics to the science of medicine. *Nelson Loose Leaf Medicine*, v. 7, pp. 111-127; 127A-127H.
Modern methods of handling hospital statistics. *Johns Hopkins Hospital Bulletin*, v. 32, pp, 184-194.
A statistical note on epidemic encephalitis. *Ibid.*, pp. 221-225.
Studies on the physiology of reproduction in the domestic fowl. XVIII. Further observations on the anatomical basis of fecundity. *Journal of Experimental Zoology*, v. 34, pp. 101-118. By R. P. and W. F. Schoppe.
A statistical note [accompanying a paper by John T. King, Jr. on "Determination of the basal metabolism from the carbon-dioxide elimination."] *Johns Hopkins Hospital Bulletin*, v. 32, pp. 285-286.
Biometric data on infant mortality in the United States Birth Registration Area, 1915-1918. *American Journal of Hygiene*, v. 1, pp. 419-439.
The vitality of the peoples of America. *Ibid.*, pp. 592-674.
Experimental studies on the duration of life. I. Introductory discussion of the duration of life in *Drosophila*. *American Naturalist*, v. 55, pp. 481-509. By R. P. and Sylvia L. Parker.
Jennings anniversary celebration. *Science*, N. S., v. 54, pp. 25-26. [Unsigned.]
Some biological aspects of human mortality. *Proceedings of the Pathological Society of Philadelphia*, N. S., v. 23, pp. 84-87.

*1922*

Review of *The Friendly Arctic* by V. Stefansson. *Science*, v. 55, pp. 320-321.
The vital index of the population of England and Wales, 1838-1920. *Proceedings of the National Academy of Sciences*, v. 8, pp. 71-76. By R. P. and Magdalen H. Burger.
Seasonal fluctuations of the vital index of a population. *Ibid.*, pp. 76-78.
A note on the inheritance of duration of life in man. *American Journal of Hygiene*, v. 2, pp. 229-233.

Experimental studies on the duration of life. II. Hereditary differences in duration of life in line-bred strains of *Drosophila*. *American Naturalist*, v 56, pp. 174-187. By R. P. and Sylvia L. Parker.

Preliminary note on a biometrical study of the relations of certain viscera in tuberculosis *Proceedings of the National Academy of Sciences*, v. 8, pp. 125-128. By R. P. and Agnes Latimer Bacon.

Experimental studies on the duration of life. III. The effect of successive etherizations on the duration of life of *Drosophila*. *American Naturalist*, v. 56, pp. 275-280. By R. P. and S L. Parker.

Biometrical studies in pathology. I. The quantitative relations of certain viscera in tuberculosis. *Johns Hopkins Hospital Reports*, v. 21, fasc. III, pp. 157-230. By R. P. and Agnes L. Bacon

On the influence of density of population upon the rate of reproduction in *Drosophila* *Proceedings of the National Academy of Sciences*, v. 8, pp. 212-219. By R. P. and Sylvia L. Parker.

Experimental studies on the duration of life. IV. Data on the influence of density of population on duration of life in *Drosophila*. *American Naturalist*, v. 56, pp. 312-321. By R. P. and S. L. Parker.

New data on the influence of alcohol on the expectation of life in man. *American Journal of Hygiene*, v. 2, pp. 463-466.

The population problem. *Geographical Review*, v. 12, pp. 636-645.

World overcrowding. *New York Times*, Sunday, October 8. 1 p.

Experimental studies on the duration of life. V On the influence of certain environmental factors on duration of life in *Drosophila* *American Naturalist*, v. 56, pp. 385-398. By R. P. and S. L. Parker.

Experimental studies on the duration of life. VI. A comparison of the laws of mortality in *Drosophila* and in man *Ibid.*, pp. 398-405.

A further note on the age index of a population. *Proceedings of the National Academy of Sciences*, v. 8, pp. 300-303. By R. P. and T. J. LeBlanc.

The statistical evaluation of public health activities. *American Journal of Public Health*, v. 12, pp. 915-921.

[BOOK] The Biology of Death. Being a Series of Lectures Delivered at the Lowell Institute in Boston in December 1920. *Philadelphia* and *London* (J. B. Lippincott Co.). 275 pp.

Preliminary discussion of the correlation between illiteracy and mortality in American cities. *American Journal of Hygiene*, v. 2, pp. 587-600. By R. P. and Morrill L. Ilsley.

Trends of modern biology. *Science*, N. S., v. 56, pp. 581-592.

Biometrical studies in pathology. II. Pathometric index numbers: preliminary account of a quantitative method of evaluating pathological phenomena. *Johns Hopkins Hospital Bulletin*, v. 33, pp. 406-412.

A further note on the mathematical theory of population growth. *Proceedings of the National Academy of Sciences*, v. 8, pp. 365-368. By R. P. and L. J. Reed.

Review of *United States Life Tables 1890, 1901, 1910, and 1901-1910*, by James W. Glover. *Science* N. S., v. 56, pp. 756-757.
Introduction to "An Elementary Treatise on Frequency Curves and their Application in the Analysis of Death Curves and Life Tables" by Arne Fisher. *New York* (Macmillan), pp. i-iii.

*1923*

The age at death of the parents of the tuberculous and the cancerous. *American Journal of Hygiene*, v. 3, pp. 71-89.
New experimental data on the influence of density of population upon duration of life in *Drosophila*. Prelimintary Note. *Ibid.*, pp. 94-97. By R. P. and S. L. Parker.
A comparison of the mortality of certain lower organisms with that of man. *Science*, v. 57, pp. 209-212. By R. P. and Carl R. Doering.
Some eugenic aspects of the problem of population. *Scientific Papers . . . Second International Congress of Eugenics, Vol. II. Eugenics in Race and State*, pp. 212-214.
The menace of population growth. *Birth Control Review*, v. 7, pp. 65-67.
The population problem. *Literary Review*, v. 3, p. 533.
Experimental studies on the duration of life. VII. The Mendelian inheritance of duration of life in crosses of wild type and quintuple stocks of *Drosophila melanogaster*. *American Naturalist*, v. 57, pp. 153-192. By R. P., S. L. Parker, and B. M. Gonzalez.
Predicted growth of Population of New York and its Environs. *New York* (Plan of New York and its Environs). Pp. 42. By R. P. and L. J. Reed.
Interrelations of the biometric and experimental methods of acquiring knowledge: with special reference to the problem of the duration of life. *The Harvey Society Lectures 1921-1922*, pp. 179-205. [Also reprinted in *Metron*, v. 2, pp. 697-721.]
Common sense about living. *Literary Review*, v. 3, p. 828.
How little we know! *The Survey*, v. 50, pp. 441-442.
Review of *Heredity and Environment in the Development of Men* (5th edit.). *Birth Control Review*, v. 7, p. 183; of *The Mathematical Theory of Probabilities* etc., by Arne Fisher and *A Treatise on Probability* by J. M. Keynes. *Science*, v. 58, pp. 51-52.
On the mathematical theory of population growth. *Metron*, v. 3, pp. 6-19. By R. P. and L. J. Reed.
[BOOK] Introduction to Medical Biometry and Statistics. *Philadelphia* and *London* (W. B. Saunders Co.). 379 pp.
Alcohol and mortality. *In* "The Action of Alcohol on Man." *London* (Longmans, Green and Co.), pp. 213-286.
Duration of life as an index of constitutional fitness. *Poultry Science*, v. 3, pp. 1-10.

Review of *Contraception (Birth Control)* by Marie C. Stopes. *Birth Control Review*, v 7, pp. 335-336
The population problem. *Literary Review*, v. 4, p. 384.
The absolute weight of the heart and the spleen. *Proceedings of the National Academy of Sciences*, v. 9, pp. 428-433. By R. P. and A. L. Bacon.

*1924*

Alcohol and the duration of life. *The American Mercury*, v. 1, pp. 213-215
Preliminary account of an investigation of factors influencing longevity. *Journal of the American Medical Association*, v. 82, pp 259-264.
Biometrical studies in pathology. III. The absolute weight of the heart and spleen in tuberculous persons. *Johns Hopkins Hospital Reports*, v. 21, fasc. v, pp. 297-377. By R. P. and Agnes L. Bacon.
Experimental studies on the duration of life. IX. New life tables for *Drosophila*. *American Naturalist*, v. 58, pp. 71-82. By R. P. and S. L. Parker.
Review of *Population* by H. Wright, and *Population Problems* by E B. Reuter. *Baltimore Evening Sun*, March 8, p. 6.
Experimental studies on the duration of life. X. The duration of life of *Drosophila melanogaster* in the complete absence of food. *American Naturalist*, v. 58, pp. 193-218 By R. P. and S. L. Parker.
The probable error of certain constants of the population growth curve. *American Journal of Hygiene*, v. 4, pp. 237-240. By R. P. and L. J. Reed.
Alcohol and life duration. *British Medical Journal*, May 31, pp 948-950.
The influence of alcohol on duration of life. *Proceedings of the National Academy of Sciences*, v. 10, pp. 231-237.
Starvation life curves. *Nature*, v. 113, p. 854.
The racial effect of alcohol. *Eugenics Review*, v. 16, pp. 9-30.
The influence of alcohol on duration of life. *Science*, v. 59, p. 445.
The curve of population growth. *Proceedings of the American Philosophical Society*, v. 63, pp. 10-17.
[BOOK] Studies in Human Biology. *Baltimore* (Williams and Wilkins Co.). 653 pp.
The influence of physical activity upon mortality. A reprint of Chapter XI of *Studies in Human Biology*, pp. 298-354. By R. P. and Paul R. Hawley.
The biology of population growth. *American Mercury*, v. 3, pp. 293-305.
The racial origin of almshouse paupers in the United States. *Science*, v. 60, pp. 394-397.
Humanizing biology. *Saturday Review of Literature*, v. 1, p. 262.
Note on Dr. John Brownlee's paper on age vitality. *American Naturalist*, v. 58, pp. 564-566.
Biologia Generalis. *Science*, v. 60, p. 424.
Microbes, the unseen foe. *Baltimore Evening Sun*, November 15.

[BOOK] Liv och Dod. Biologiskt-statistika Studier. Till Svenska av Ivar Tragardh. *Stockholm* (Hugo Gebers Förlog). Pp. xvi — 191. [Swedish translation of *The Biology of Death.*]

*1925*

Looking ahead in business. *Baltimore Evening Sun*, February 11.

Skew-growth curves. *Proceedings of the National Academy of Sciences*, v. 11, pp. 16-22. By R. P. and L. J. Reed.

The Life, Letters and Labours of Francis Galton. [Review of Pearson's biography of Galton, Vols. I and II.] *Science*, v. 61, pp. 209-212.

Almshouse paupers in the United States, *Ibid.*, p. 285. [Reprinted with the title "Facts, reasons and pauperism." Same bibliographic locus.]

On the inheritance of duration of life. *Memorial Publication in Honor of 100th Birthday of J. G. Mendel Issued by the Czechoslovac Eugenics Society in Prague*, pp. 175-192.

Distribution of physicians in the United States. A commentary on the report of the General Education Board. *Journal of the American Medical Association*, v. 84, pp. 1024-1028. [Also printed in *Proceedings . . . Annual Congress on Medical Education, Medical Licensure, Public Health and Hospitals. Chicago March 9-12, 1925. Chicago* (American Medical Association), pp. 62-66. Discussion, p. 70.]

Educational and professional standards for vital statisticians. *American Journal of Public Health*, v. 15, pp. 518-520. By W. W. Kopf, O. R. Eichel, R. P. and E. Sydenstricker.

Review of Swinburne's Population and the Social Problem. *Baltimore Evening Sun*, June 13, p. 8.

The reading of graduate students. *Scientific Monthly*, v. 21, pp. 34-44.

Business cycles and their effect on births and deaths. *Baltimore Evening Sun*, July 25, p. 6.

Biologja wzrostu ludności. [The biology of population growth.] Medecyny Doswiadozalnej i Społicznej, T. 4, Zes. 3-6, pp. (of reprint) 1-19. [Polish translation by M. Kacprzak.]

Review of *Is Unemployment Inevitable? Eugenics Review (London)*, v. 17, pp. 107-108.

The menace of population growth. In *Birth Control Facts and Responsibilities. A Symposium dealing with this Important Subject from a Number of Angles.* Edited by Adolf Meyer. *Baltimore* (Williams and Wilkins Co.), pp. 50-61.

The differential birth rate. *Birth Control Review*, v. 9, pp. 278-279; 300-302.

Some recent biological texts. *Biologia Generalis*, v. 1, pp. 501-504.

[BOOK] The Biology of Population Growth. *New York* (Alfred A. Knopf). Pp. xiv + 260.

Adam Smith on medical education and related matters. *Journal of the American Medical Association*, v. 85, pp. 1663-1665.

The biology of health. *The American Mercury*, v. 6, pp. 385-392.

Vital statistics of the National Academy of Sciences. I Age at election. *Proceedings of the National Academy of Sciences,* v. 11, pp. 752-757.
Vital statistics of the National Academy of Sciences. II. Election of young men. *Ibid.,* pp. 757-760.
Vital statistics of the National Academy of Sciences. III. Mortality. *Ibid.,* pp. 760-765.
Vital statistics of the National Academy of Sciences. IV. The present limitation to total membership and other matters. *Ibid.,* pp. 765-768.

*1926*

The influence of alcohol upon the growth of seedlings. *Journal of General Physiology (Jacques Loeb Memorial Volume),* v. 8, pp. 215-231. By R. P. and Agnes Allen.
Foreword. *Quarterly Review of Biology,* v. 1, No. 1, pp. 1-3.
New biological books. Brief notices. *Ibid.,* 124-137; 294-314; 444-464; 584-605. [Unsigned.]
Havelock Ellis and human biology. *Birth Control Review,* v. 10, pp. 50-51.
Span of life and average duration of life. *Natural History,* v. 26, pp. 26-30.
The differential birth rate. *Problems of Overpopulation,* being Vol. II of The *Sixth International Neo-Malthusian and Birth Control Conference, New York, 1926.* Pp. 19-29.
Dean Swift and the goldfish. *American Speech,* v. 1, pp. 315-316.
Biometrical studies in pathology. IV. Statistical characteristics of a population composed of necropsied persons. *Archives of Pathology and Laboratory Medicine,* v. 1, pp. 329-347. By R. P. and Agnes L. Bacon.
A philosopher for the bloc. *Baltimore Evening Sun,* April 6.
Review of *Malthus and His Work* by James Bonar. *Birth Control Review,* v. 10, p. 132.
Vital statistics of the National Academy of Sciences. V. The growth of the Academy. *Proceedings of the National Academy of Sciences,* v. 12, pp. 258-261.
A synthetic medium for the cultivation of *Drosophila.* Preliminary note. *Journal of General Physiology,* v. 9, pp. 513-519.
The constitutional elements in the etiology of pneumonia. *Proceedings of the Society of Experimental Biology and Medicine,* v. 23, pp. 573-576.
Review of *The Natural Increase of Mankind* by J. Shirley Sweeney. *Saturday Review of Literature,* v. 2, p. 796.
New data on differential fertility in the United States. *American Journal of Hygiene,* v. 6, pp. 610-616.
Culture media for *Drosophila.* I. Changes in hydrogen ion concentration of the medium. *American Naturalist,* v. 60, pp. 347-357. By R. P. and W. B. D. Penniman.
Culture media for *Drosophila.* II. A new synthetic medium and its influence on fertility at different densities of population. *Ibid.,* pp. 357-366. By R. P., Agnes Allen, and W. B. D. Penniman.

Death: Why and wherefore. *Encyclopedia Britannica*, 13th Edition, v. 1, pp. 826-828. [Also reprinted in *Seven Famous Reprints from the New Thirteenth Edition of the Encyclopedia Britannica and Biographies of the Authors. New York* and *London*, 1927, pp. 82-93. (Biographical sketch, p. 81).]

The revival of the population question. *Readings in Civic Sociology* (By E. A. Ross and Mary E. McCaull). *New York* (World Book Co.) [One page.]

The cost of biological books in 1926. *Quarterly Review of Biology*, v. 1, pp. 606-608.

[BOOK] Alcohol and Longevity. *New York* (Alfred A. Knopf, Inc.). Pp. xii + 273.

Alcool e longevità. *Le Assicurazioni Sociali*, T. 2, No. 5, pp. 22-47.

A time recorder for quantitative work in animal behavior. *Journal of the Washington Academy of Science*, v. 16, pp. 541-543.

Report of the Director of the Institute for Biological Research. *Report of the President of the University, 1925-1926, Johns Hopkins University Circular No. 375*, pp. 178-182.

*1927*

Bradford's Life of Darwin. *Baltimore Evening Sun*, Jan. 15.

Note. *American Journal of Obstetrics and Gynecology*, v. 13, pp. 35-36.

A biometric study of the relative cell volume of human blood, in normal and tuberculous males. *Bulletin of the Johns Hopkins Hospital*, v. 40, pp. 3-32. By R. P. and J. R. Miner.

Notes on the growing of seedlings for physiological experimentation. *Proceedings of the Society for Experimental Biology and Medicine*, v. 24, pp. 439-444. By R. P. and Agnes L. Allen.

On the distribution of differences in vitality among individuals. *American Naturalist*, v. 61, pp. 113-131. [Abstract of this paper, with same title, published in *Archives of Pathology and Laboratory Medicine*, v. 3, p. 549, 1927.]

The graphic representation of relative variability. *Science*, v. 65, pp. 237-241.

Differential fertility. *Quarterly Review of Biology*, v. 2, pp. 102-118.

[BOOK] To Begin With. Being Prophylaxis against Pedantry. *New York* (Alfred A. Knopf, Inc.). Pp. ix + 96.

Review of *A Statistical Study of Three Thousand Autopsies* by William Ophüls. *Archives of Pathology and Laboratory Medicine*, v. 3, pp. 742-744. [Unsigned.]

List of dates of birth of members of the National Academy of Sciences. *Annual Report of the National Academy of Sciences Fiscal Year 1925-1926*, pp. 179-185. [Unsigned.]

The constitutional factor in breakdown of the respiratory system. *Annals of Eugenics (London)*, v. 2, pp. 1-24, 1 plate.

Biometrical studies in pathology. V. The racial and age incidence of cancer and of other malignant tumors. *Archives of Pathology and Laboratory Medicine*, v. 3, pp. 963-992. By R. P. and Agnes L. Bacon.

Experimental studies on the duration of life. XI. Density of population and life duration in *Drosophila*. *American Naturalist*, v. 61, pp. 289-318. By R. P., J. R. Miner, and S. L. Parker.

The biology of population growth. *Birth Control Review*, v. 11, pp. 236-237; 247; 260-263.

On the summation of logistic curves. *Journal of the Royal Statistical Society (London)*, v. 90, pp. 729-746. By Lowell J. Reed and R. P.

The biology of superiority. *The American Mercury*, v. 12, pp. 257-266.

At last, a "family doctor book" that is honest. *Baltimore Evening Sun*, November 26.

Bevolkningstillvaxtens biologi. *Nordisk Statistisk Tidskrift*, v. 6, pp. 195-213.

The indigenous native population of Algeria in 1926. *Science*, v. 66, pp. 593-594.

Report of the Director of the Institute for Biological Research. *Report of the President of the University, 1926-1927. Johns Hopkins University Circular No. 385*, pp. 149-154.

The growth of populations. *Quarterly Review of Biology*, v. 2, pp. 532-548.

The cost of biological books in 1927. *Ibid.*, pp. 581-583.

The biology of population growth. *Proceedings of the World Population Conference, Geneva*, 1927, pp. 22-38. [French translation under the title L'accroissement de la population au point de vue biologique (of French edition of *Proceedings*), pp. 3-25]

Biometry and vital statistics in relation to the science of medicine. *Nelson Loose-Leaf Medicine. Prevention and Public Health*, v. II, pp. 127-150.

*1928*

[BOOK] The Rate of Living. Being an Account of Some Experimental Studies on the Biology of Life Duration. *New York* (Alfred A. Knopf). Pp. [16] + 185.

New data on alcohol and duration of life. *Nature*, v. 121, pp. 15-16. By R. P. and Agnes L. Bacon.

The length of life of the moderate drinker. *The American Mercury*, v. 13, pp. 198-200.

The growth of seedlings of the cantaloupe, *Cucumis melo*, in the absence of exogenous food and light. *Proceedings of the National Academy of Sciences*, v. 14, pp. 1-4. By R. P., Agnes A. Winsor, and J. R. Miner.

[BOOK] The Present Status of Eugenics. *Hanover, N. H.* (The Sociological Press). Pp. 20.

Review of *Emergent Evolution and the Development of Societies* by W. M. Wheeler. *Baltimore Evening Sun*, April 7, p. 6.

Self destruction. *Saturday Review of Literature*, v. 4, p. 822.
The International Population Union. *Science*, v. 67, pp. 435-436.
Eugenics. *Verhandlungen des V. Internationalen Kongresses für Vererbungswissenschaft, Berlin, 1927.* Supplement. Bd. I, pp. 261-282.
The population problem. I. Population growth. *Time and Tide (London)*, v. 9, pp. 482-483
Evolution and mortality. *Quarterly Review of Biology*, v. 3, pp. 271-280.
Biometrical studies in pathology. VI. The primary site of cancers and other malignant tumors. *Archives of Pathology*, v. 6, pp. 67-89. By R. P. and Agnes L. Bacon.
Ecce homo omnisciens. *Saturday Review of Literature*, v. 4, p. 999.
Experiments on longevity. *Quarterly Review of Biology*, v. 3, pp. 391-407.
Interim report of the proceedings of the First General Assembly of the International Union for the Scientific Study of Population Problems. *Journal of the American Statistical Association*, v. 23, pp. 306-317. [Unsigned.]
Alcohol and life duration. *International Clinics*, 38th ser., v. 3, pp. 27-51.
Cancer from the viewpoint of the human biologist. *Ibid*, pp. 53-77. [Second of the 11th series of Harrington Lectures.]
On the pathological relations between cancer and tuberculosis. *Proceedings of the Society for Experimental Biology and Medicine*, v. 26, pp. 73-75.
Introduction. In *What is Life?*, by Augusta Gaskell. Pp. 13-17.
The psychology of prohibition. *American Mercury*, v. 15, pp. 385-394.
The senior fellowships of St. John's College. *School and Society*, v. 28, pp. 626-627.
Progress report on an investigation in race pathology. *Southern Medical Journal*, v. 21, pp. 1001-1005.
Report of the Director of the Institute for Biological Research. *Report of the President of the University, 1927-1928. Johns Hopkins University Circular No. 396*, pp. 152-161.
Nieuwe gegevens omtrent alcohol en levensduur. *Wetenschappelijke Bladen*, Bd. 2, pp. 67-70. By R. P., and Agnes L. Bacon.
The cost of biological books in 1928. *Quarterly Review of Biology*, v. 3, pp. 600-603.
The form of the growth curve of the cantaloupe *(Cucumis melo)* under field conditions. *Proceedings of the National Academy of Sciences*, v. 14, pp. 895-901. By R. P., Charles P. Winsor, and Florence B. White.

*1929*

Experimental studies on the duration of life. XII. Influence of temperature during the larval period and adult life on the duration of life of the imago of *Drosophila melanogaster*. *American Naturalist*, v. 63, pp. 37-67. By W. W. Alpatov, and R. P.

Dictionary of American Biography, source book for human biology. *Baltimore Evening. Sun,* January 12.
Zur Psychologie des Alkoholverbots. *Das Tage Buch,* July 10, Heft 1, pp. 7-12.
Statistical report on the first year's operations of the Bureau for Contraceptive Advice. *First Report of the Bureau for Contraceptive Advice, Baltimore, 1929,* pp. 2-6.
"Human Biology." *Science,* v. 69, pp. 132-133.
Cancer and tuberculosis. *American Journal of Hygiene,* v. 9, pp. 97-159.
Science, metaphysics and blood. *Science,* v. 69, pp. 161-163.
The International Union for the Scientific Investigation of Population Problems. *Eugenical News,* v. 14, pp. 18-21.
Foreword. *Human Biology,* v. 1, No. 1, pp. 1-3.
Studies on constitution. I. Methods. *Ibid.,* pp. 10-56. By R. P., Alan C. Sutton, W. T. Howard, Jr., and Margaret G. Rioch.
A note on the mortality of brewery employees. *Ibid.,* pp. 136-138.
Mr. Cranium's lecture. *Ibid.,* pp. 139-142.
Recent literature useful in the study of human biology. *Ibid.,* pp. 144-152; 286-304; 431-444; 572-588.
The International Union for the Scientific Investigation of Population Problems. *Johns Hopkins Alumni Magazine,* v. 17, pp. 226-232.
Births and deaths. *Baltimore Evening Sun,* March 2, p. 8. [Unsigned.]
The population of an area around Chicago and the Logistic curve. *Journal of the American Statistical Association,* v. 24, pp. 66-67. By R. P., and L. J. Reed.
The new Britannica—a unique record of civilization. In *The New Britannica, 14th Edition. New York,* pp. 13-15.
Age changes in alcohol tolerance in *Drosophila melanogaster. Proceedings of the National Academy of Sciences,* v. 15, pp. 425-429. By R. P., Florence B. White, and J. R. Miner.
Experimental treatment of cancer with tuberculin. *Lancet,* v. 216, pp. 1078-1080. By R. P., Alan C. Sutton, and W. T. Howard, Jr.
Biological factors in Negro mortality. *Human Biology,* v. 1, pp. 229-249.
A note on the association of diseases. *Science,* v. 70, pp. 191-192.
Editorial note. *Quarterly Review of Biology,* v. 4, p. 297.
Introductory note. *Bulletin of the International Union for the Scientific Study of Population Problems,* v. 1, No. 1, p. 1. [Unsigned.]
Death, Biological aspects of. *Encyclopedia Britannica, 14th Edition,* v. 7, pp. 110-112.
Changes in the incidence of mortality at advanced ages. *Human Biology,* v. 1, pp. 558-561.
Constitutional somatology. *Ibid,* pp. 283-284.
Dr. John Cross on physiognomy and constitution. *Ibid.,* pp. 426-430.
John Hunter on appetites and aging. *Ibid.,* pp. 565-571.

Report of the Director of the Institute for Biological Research. *Report of the President of the University, 1928-1929. Johns Hopkins University Circular No. 407*, pp. 173-187.

*1930*

Alcohol. Biological aspects. *Encyclopedia of the Social Sciences*, v. 1, pp. 620-622.

Some Aspects of the Biology of Human Populations. *Human Biology and Racial Welfare* (Edited by E. V. Cowdry and published by Paul R. Hoeber, Inc., New York), pp. 515-552.

Cobbes Questions and Answers, 1614. *Human Biology*, v. 2, pp. 137-144.

[BOOK] To Begin With. Being Prophylaxis Against Pedantry. Revised and Enlarged Edition. *New York* (Alfred A. Knopf, Inc.). Pp. [16 unnumbered] + 123.

Recent literature useful in the study of human biology. *Human Biology*, v. 2, pp. 145-158; 292-302; 441-456; 569-581.

Requirements of a proof that natural selection has altered a race. *Scientia*, v. 47, pp. 175-186. [Translated into French by Henry de Varigny: Que faut-il pour prouver que la sélection naturelle a modifié une race? *Supplement, Scientia*, v. 47, pp. 84-94.]

Statistical report on the second year's operation of the Bureau for Contraceptive Advice. *Second Report of the Bureau for Contraceptive Advice, Baltimore*, pp 2-10.

Skepticism reconciled. *Saturday Review of Literature*, v. 6, p. 1090.

Biological Factors in Negro Mortality. *The Negro in American Civilization* (By Charles S. Johnson, published by Henry Holt and Co., New York), pp. 413-431.

The logistic curve and the census count of 1930. *Science*, v. 72, pp. 399-401. By R. P. and L. J. Reed.

[BOOK] Alcohol und Lebensdauer. *Hannover* (Norddeutsches Druck- und Verlagshaus). Pp. 263.

[BOOK] Introduction to Medical Biometry and Statistics. Second Edition, Revised and Enlarged. *Philadelphia* and *London* (W. B. Saunders Co.). Pp. 459.

Report of the Director of the Institute for Biological Research. *Report of the President of the University 1929-1930. Johns Hopkins University Circular No. 419*, pp. 168-178.

An eighteenth century evolutionist. *Human Biology*, v. 2, pp. 559-566.

The history of a gesture. *Ibid.*, pp. 566-568.

*1931*

The Life, Letters and Labours of Francis Galton. *Science*, v. 73, pp. 238-240.

Longevity: a pedigree. *Human Biology*, v. 3, pp. 133-137.

Harvey's post-mortem examination of Thomas Parr. *Ibid.*, pp. 138-142.

Recent literature useful in the study of human biololgy. *Ibid.*, pp. 143-156; 289-301; 442-458; 586-600.

Statistical report on the third year's operations of the Bureau for Contraceptive Advice. *Third Report of the Bureau for Contraceptive Advice, Baltimore*, pp. 4-14.

Superficie, population et religions de la terre. *Journal de la Société de Statistique de Paris*, T. 72, p. 143.

Studies on human longevity. IV. The inheritance of longevity. Preliminary report. *Human Biology*, v. 3, pp. 245-269.

Erratum. *Ibid.*, p. 288.

Alcool e biologia umana. *Scritti biologici*, T. 6, pp. 1-12.

Report of President at the Second General Assembly of the International Union for the Scientific Investigation of Population Problems. *Bulletin of the International Union for the Scientific Investigation of Population Problems*, v. 2, pp. 49-53.

Some notes on the Census of Religious Bodies, 1926. *Journal of Social Psychology*, v. 2, pp. 417-432.

A fine survey of biology. *Baltimore Evening Sun*, November 14, p. 6.

On the alleged lethal effects of sexual continence in the Holy Land. *Human Biology*, v. 3, pp. 577-585.

*1932*

Studies on human longevity. V. Constitutional factors in mortality at advanced ages. *Human Biology*, v. 4, pp 80-118. By R. P. and T. Raenkham.

An explanatory note regarding a more detailed classification of recent literature useful in the study of human biology. *Ibid.*, pp. 131-133.

Recent literature useful in the study of human biology. *Ibid.*, pp. 133-153; 289-305; 435-451; 584-602.

Statistical report on the fourth year's operations of the Bureau for Contraceptive Advice. *Fourth Report of the Bureau for Contraceptive Advice, Baltimore*, pp. 3-15.

A table for ascertaining elapsed time in years and decimals of a year between any two dates. *Milbank Memorial Fund Quarterly Bulletin*, v. 10, pp. 151-154. By R. P., and J. R. Miner.

Report on funds for publication of research. *Annual Report of the National Academy of Sciences, Fiscal Year 1930-1931*, pp. 20-27. By E. G. Conklin, A. L. Day, O. Veblen, and R. P.

Variation in *Goniobasis virginica* and *Anculosa carinata* under natural conditions. I. The problem, material, and methods. *Biologia Generalis*, v. 8, pp. 607-630. Plates XIV and XV. By Joshua L. Baily, Jr., R. P., and C. P. Winsor.

The influence of density of population upon egg production in *Drosophila melanogaster*. *Journal of Experimental Zoology*, v. 63, pp. 57-84.

Contraception and fertility in 2,000 women. *Human Biology*, v. 4, pp. 363-407.

Some data on fertility and economic status. *Ibid.*, pp. 525-553.
Tobias Venner and his Via Recta. *Ibid.*, pp. 558-583.

*1933*

Preliminary notes on a cooperative investigation of family limitation. *Milbank Memorial Fund Quarterly Bulletin*, v. 11, pp. 37-60.
Statistical report on the fifth year's operations of the Bureau for Contraceptive Advice. *Fifth Report of the Bureau for Contraceptive Advice, Baltimore*, pp. 5-17.
Available food, relative growth and duration of life in seedlings of *Cucumis melo*. *Proceedings of the National Academy of Sciences*, v. 19, pp. 228-233. By Sophia A. Gould, R. P., Thomas I. Edwards, and J. R. Miner.
Recent literature useful in the study of human biology. *Human Biology*, v. 5, pp. 135-154; 295-312; 520-540; 722-740.
Professors go trending. *Baltimore Evening Sun*, March 1, p. 15.
America today and maybe tomorrow. *Quarterly Review of Biology*, v. 8, pp. 96-101.
The way of the reformer. *The Nation*, v. 136, pp. 588-589, May 24.
Variation in *Goniobasis virginica* and *Anculosa carinata* under natural conditions. II. The relation between size of the shells and environmental factors. *Biologia Generalis*, v. 9, pp. 301-336, plates VI-VIII. By Joshua L. Baily, Jr., R. P., and C. P. Winsor.
The inheritance of longevity. *Explorations in Science, Schenectady, N. Y.* (Research Laboratory, General Electric Co.) Pp. 73-75. [Text of radio broadcast.]
The Rotarian hoof. *American Mercury*, v. 29, p. 499. [Signed Stringfellow Coolidge.]
Factors in human fertility and their statistical evaluation. *The Lancet*, v. 225, pp. 607-611.
Variation in *Goniobasis virginica* and *Anculosa carinata* under natural conditions. III. Correlations, shape of shells, and conclusions. *Biologia Generalis*, v. 9, 2 Halfte, pp. 48-69. By J. L. Baily, Jr., R. P., and C. P. Winsor.
A classification and code of occupations. *Human Biology*, v. 5, pp. 491-505.
[BOOK] Constitution and Health. *London* (Kegan Paul, Trench, Trübner and Co.). Pp. 97. [Psyche Miniatures, General Series, No. 60.]
On the frequency of the use of contraceptive methods, and their effectiveness as used by a sample of American women. *XXI<sup>e</sup> Session de l'Institut Internationale de Statistique*, Sect. I. Comm. Pp. 20.

*1934*

Studies on human longevity. VI. The distribution and correlation of variation in the total immediate ancestral longevity of nonagenarians and centenarians, in relation to the inheritance of duration of life. *Human Biology*, v. 6, pp. 98-222. By R. P. and Ruth DeWitt Pearl.

Recent literature useful in the study of human biology. *Ibid.*, pp. 241-270; 408-430; 564-593; 722-737.
Review of La fertilità dei biotipi. *Saggio di demographia constituzionalistica* by Marcello Boldrini. *American Journal of Sociology*, v. 39, pp. 709-712.
Aeration and growth of cantaloupe seedlings. *American Journal of Botany*, v. 21, pp. 242-250. By R. P., T. I. Edwards, Agnes A. Winsor, and C. P. Winsor.
The growth of *Cucumis melo* seedlings at different temperatures. *Journal of General Physiology*, v. 17, pp. 687-700. By R. P., T. I. Edwards, and J. R. Miner.
Contraception and fertility in 4945 married women. A second report on a study of family limitation. *Human Biology*, v. 6, pp. 355-401.
[BOOK] The Ancestry of the Long-Lived. *Baltimore* and *London* (The Johns Hopkins Press; Humphrey Milford, Oxford University Press). Pp. xiv + 168. By R. P. and Ruth DeWitt Pearl.
Constitutional factors in longevity. *Zeitschrift für Morphologie und Anthropologie*, Bd. 34, pp. 314-320. [Eugen Fischer-Festband.]
[Remarks in a Symposium on Science and Industry in the Coming Century. Chicago, May 25, 1934.] *Scientific Monthly*, v. 39, pp. 76-77.
Scientists into philosophers. *Baltimore Evening Sun*, August 25.
Second progress report on a study of family limitation. *Milbank Memorial Fund Quarterly*, v. 12, pp. 248-269.
On the effects of partial removal of the cotyledons upon the growth and duration of life of cantaloupe seedlings without exogenous food. *Annals of Botany*, v. 48, pp. 575-599. By Sophia A. Gould, R. P., T. I. Edwards, and J. R. Miner.
Influence of temperature and nutrition on the growth and duration of life of *Cucumis melo* seedlings. *Botanical Gazette*, v. 96, pp. 118-135. By T. I. Edwards, R. P., and S. A. Gould.
Foreword. *Working Dogs* by Elliott Humphrey and Lucien Warner. *Baltimore* (Johns Hopkins Press).
The weight of the Negro brain. *Science*, v. 80, pp. 431-434.
L'organisation et la travail de la section de biologie à l'École d'Hygiène et de Santé Publique de l'Université Johns Hopkins. *Biotypologie*, T. 2, pp. 105-122.
The dynamics of population. *Science*, v. 80, pp. 504-505.
Foreword. *The Struggle for Existence* by G. F. Gause. *Baltimore* (Williams and Wilkins Co.), pp. v-vi.
Studies on constitution. II. Somatological differences associated with diseases of the heart in white males. *Human Biology*, v. 6, pp. 650-713. By R. P., and Antonio Ciocco. [No. III in the series of Studies on constitution was by Antonio Ciocco alone, and hence does not appear in the present bibliography.]

*1935*

What are your chances of living a long time? *Cosmopolitan,* v. 98, pp. 44-45 and 181.

On the comparison of groups in respect of a number of measured characters. *Human Biology,* v. 7, pp. 95-107. By R. P. and J. R. Miner.

Recent literature useful in the study of human biology. *Ibid.,* pp. 121-150; 272-301; 443-467; 616-633.

How long will you live? *Forum,* v. 93, pp. 172-173.

The business of living a long time. *Reader's Digest,* v. 26, No. 155, pp. 59-62.

Experimental studies on the duration of life. XIV. The comparative mortality of certain lower organisms. *Quarterly Review of Biology,* v. 10, pp. 60-79. By R. P. and J. R. Miner.

Biology and human trends. *Journal of the Washington Academy of Sciences,* v. 25, pp. 253-272. [Reprinted in 1936, with slight alterations, in *Smithsonian Institution Annual Report for 1935,* pp. 327-344.]

Human biology in schools and colleges. *School and Society,* v. 42, pp. 111-118.

A biometric study of the endocrine organs in relation to mental disease. Part I. *Human Biology,* v. 7, pp. 350-391. By R. P., Marjorie Gooch, and Walter Freeman.

Dr. Carrel ponders the nature and soul of man. *New York Times Book Review,* September 29, pp. 3 and 23.

Birth rate in recent years. *The World Today* (New York, Encyclopedia Britannica), v. 3, pp. 27-29.

On the incidence of tuberculosis in the offspring of tuberculous parents. *Science,* v. 82, pp. 539-540.

A biometric study of the endocrine organs in relation to mental disease. Part II. *Human Biology,* v. 7, pp. 555-607. By R. P., Marjorie Gooch, and Walter Freeman.

*1936*

Biology and human progress. *Harpers Magazine,* v. 172, pp. 225-235.

War and overpopulation. *Current History,* v. 43, No. 6, March.

Studies on constitution. IV. Endocrine organ weights and somatological habitus types. *Human Biology,* v. 8, pp. 92-125. By R. P., Marjorie Gooch, J. R. Miner, and Walter Freeman.

Recent literature useful in the study of human biology. *Ibid.,* v. 8, pp. 134-160; 288-308; 459-487; 617-642.

Multiplying man. *Yale Review,* v. 25, pp. 584-602.

Historical papers in the journal "Human Biology." *Isis,* v. 24, pp. 415-418.

Fertility and contraception in urban whites and Negroes. *Science,* v. 83, pp. 503-506.

On the incidence of tuberculosis in the offspring of tuberculous parents. *Zeitschrift für Rassenkunde,* Bd. 3, pp. 301-307.

Third progress report on a study of family limitation. *Milbank Memorial Fund Quarterly*, v. 14, pp. 258-284.

Foreword. *Contraception as a Therapeutic Measure* by Bessie L. Moses. (Published by Williams and Wilkins Co., Baltimore), pp. xi-xiii.

Constitutional factors in diseases of the cardiovascular-renal system. *Proceedings of the 26th Annual Meeting of the Medical Section of the American Life Convention*, pp 12-38.

Review of *An American Doctor's Odyssey* by Victor Heiser. *Baltimore Evening Sun*, September 5, p. 6. [Reprinted, under the title "On doing something for your fellow man," in *Atlantic City, N. J., Union*, September 16.]

World population growth. *Human Biology*, v. 8, pp. 399-419. By R. P., and Sophia A. Gould.

Bodily habitus and endocrine pattern. *American Journal of Physical Anthropology*, v. 21, No. 2, Supplement, p. 9.

The comparative fertility of white and Negro women in American cities. *Ibid.*, p. 15.

Experimental studies on the duration of life. XV. Life tables for the pecan nut case bearer, *Acrobasis caryae* Grote. *Mémoires du Musée Royal d'Histoire Naturelle de Belgique*, 2me Serie, Fascicule 3 (Mélanges Paul Pelseneer), pp. 169-184, 1 plate.

Biology. A Correlated Curriculum. *New York* and *London* (Appleton-Century), p. 299.

Biological factors in fertility. *Annals of the American Academy of Political and Social Science*, v. 188, pp. 14-25.

Karl Pearson, 1857-1936. *Journal of the American Statistical Association*, v. 31, pp. 653-664.

Potential and actual reproductive performance in man. *Human Biology*, v. 8, pp. 508-530.

The prices of biological books in 1936. *Quarterly Review of Biology*, v. 11, pp. 492-494. By R. P., and Maud D. Pearl.

*1937*

On biological principles affecting populations; human and other. *American Naturalist*, v. 71, pp. 50-68.

Constitution et santé. Traduit de l'anglais par L. Cassin. *Biotypologie*, T. 4, pp. 1-52. [French translation of the book *Constitution and Health*, published in 1933.]

Krieg und Übervölkerung. (Uebersetzt und mit einigen Anmerkungen versehen von Adolf Meyer). *Zeitschrift für Geopolitik*, Jahrg. 14, Heft 1, pp. 31-39. [German translation of War and overpopulation, 1936.]

Variation in parity of women bearing children in the U. S. Birth Registration Area in 1930. Part I. *Human Biology*, v. 9, pp. 65-98.

Recent literature useful in the study of human biology. *Ibid.*, pp. 108-132; 253-280; 419-449; 572-595.
Fertility and contraception in New York and Chicago. *Journal of the American Medical Association*, v. 108, pp. 1385-1390.
Variation in parity of women bearing children in the U. S. Birth Registration Area in 1930. Part II. *Human Biology*, v. 9, pp. 212-244.
On the weight of the parathyroids. *Ibid.*, pp. 245-250.
Specific fertility and contraceptive rates in New York City and Chicago. *American Journal of Hygiene*, v. 25, pp. 507-519.
On the moment product-sums of curtate frequency distributions. *Human Biology*, v. 9, pp. 410-416.
Human biology. *University of Michigan Official Publications*, v. 39, No. 50, pp. 12-13.
Progress in the biological sciences. *A University between Two Centuries. The Proceedings of the 1937 Celebration of the University of Michigan. Ann Arbor* (University of Michigan Press), pp. 233-259.
The prices of biological books in 1937. *Quarterly Review of Biology*, v. 12, pp. 504-506. By R. P. and Maud D. Pearl.

*1938*

Biology. *Encyclopedia Americana*, 1938 Edition, v. 3. Pp. (of reprint) 12.
Recent literature useful in the study of human biology. *Human Biology*. v. 10, pp. 151-180; 300-326; 426-455; 580-606.
Tobacco smoking and longevity. *Science*, v. 87, pp. 216-217. [This paper constitutes No. VII in the series "Studies on human longevity"]
The search for longevity. *Scientific Monthly*, v. 46, pp. 462-483. [Also reprinted in *Landmarks in Medicine, New York* and *London* (D. Appleton-Century), 1939, pp. 231-282.]
Some notes on the contributions of Dr. John Shaw Billings to the development of vital statistics. *Bulletin of the Institute of the History of Medicine*, v. 6, pp. 387-393.
Foreword. *Youth and Sex. A Study of 1300 College Students*, by Dorothy Dunbar Bromley and Florence Huxton Britten. *New York* (Harpers), pp. xi + xiii.
The search for longevity. *Diplomate*, v. 10, pp. 92-93.
Of human folly. *Quarterly Review of Biology*, v. 13, pp. 336-342.
Long life and living. *Proceedings of the Institute of Medicine of Chicago*, v. 12, pp. 170-172.
Economic status, differential fertility and contraception as observed in the population of large cities of the United States. *Congrès International de la Population, Paris 1937*. T. 5, pp. 81-96.
Anthologia anthropologica. *Human Biology*, v. 10, pp. 576-577.
The prices of biological books in 1938. *Quarterly Review of Biology*, v. 13, pp. 491-493. By R. P. and Maud D. Pearl.

*1939*

[BOOK] The Natural History of Population. *London* and *New York* (Oxford University Press). Pp. xii + 416. [Heath Clark Lectures, University of London, delivered in 1937.]

Review of *Political Arithmetic: A Symposium of Population Studies.* Edited by Lancelot Hogben. *The Political Quarterly* (London), v. 10, pp. 135-138, January-March No.

Records of total reproduction. *Human Biology,* v. 11, pp. 144-146.

Recent literature useful in the study of human biology. *Ibid*, pp. 148-172; 290-318; 410-446; 550-579.

Between two centuries. *American Statistical Association Bulletin,* v. 1, pp. 41-44.

Review of *Mathematical Biophysics. Physicomathematical Foundations of Biology,* by N. Rashevsky. *Bulletin of the American Mathematical Society,* March No., pp. 223-224.

Patterns for living together. *Harper's Magazine,* v. 178, pp. 595-604.

The evolution of sociality. *Ecology,* v. 20, pp. 305-310.

What's happening to world population? *Science Digest,* v. 5, No. 6, pp. 8-14.

Studies on human longevity. VIII. Bodily constitution and longevity. *Proceedings of the National Academy of Sciences,* v. 25, pp. 609-616. By R. P. and W. Edwin Moffett. [Authors' abstract. Bodily constitution and longevity. *Science,* v. 90, p. 406.]

Foreword to *Physiological Group Differentiation in Lymnaea columella,* by Joshua L. Baily, Jr. P. v.

The prices of biological books in 1939. *Quarterly Review of Biology,* v. 14, pp. 500-502. By R. P. and Maud D. Pearl.

*1940*

Recent literature useful in the study of human biology. *Human Biology,* v. 12, pp. 121-140; 287-312; 432-455; 567-592.

Jewish and Christian intermarriages in Budapest: A footnote to recent social history. *Bulletin of the History of Medicine,* v. 8, pp. 497-508. By R. P. and Celeste Franklin.

An index of body build. *American Journal of Physical Anthropology,* v. 26, pp. 315-348.

The aging of populations. *Journal of the American Statistical Association,* v. 35, pp. 277-297.

Biological aspects of death. *Encyclopedia Britannica,* v. 7, pp. 110-112B.

[BOOK] Introduction to Medical Biometry and Statistics. Third Edition, revised and enlarged. *Philadelphia* and *London* (W. B. Saunders Co.). Pp. xv + 537.

A comparative examination of certain aspects of the populations of the New World. *Human Biology,* v. 12, pp. 359-402.

The logistic curve and the census count of 1940. *Science,* v. 92, pp. 486-488. By R. P., L. J. Reed and J. F. Kish.

Pregnancy rates and coitus rates. *Human Biology*, v. 12, pp. 545-558.
The prices of biological books in 1940. *Quarterly Review of Biology*, v. 15, pp. 513-516. By Maud D. Pearl and R. P.

*1941*

Experimental studies on the duration of life. XVI. Life tables for the flour beetle *Tribolium confusum* Duval. *American Naturalist*, v. 75, pp. 5-19. By R. P., Thomas Park, and John R. Miner.
Some biological considerations about war. *American Journal of Sociology*, v. 46, pp. 487-503.